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The Dyna-METRIC Readiness Assessment Model

Motivation, Capabilities, and Use

Raymond Pyles

July 1984

Rand PROJECT AIR FORCE

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Logisticians must plan, in peacetime, for wartime. This report describes a computer model, Dyna-METRIC, that can help the logistician to forecast future performance and identify wartime logistics constraints. The report discusses the model's general functional characteristics and capabilities, and a simple example is employed to demonstrate both the model's interfaces (input files and output reports) and its use in analysis, so that analysts can apply the model to specific problems.

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Motivation, Capabilities, and Use

Raymond Pyles

July 1984

A Project AIR FORCE Report
prepared for the
United States Air Force

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PREFACE

The work documented in this report was undertaken as part of a Project AIR FORCE Resource Management Program study entitled "Improved Logistics Readiness Assessment and Management." In this project, the Air Force Logistics Command, the Pacific Air Forces, and The Rand Corporation jointly investigated how the Rand-developed resource-management model Dyna-METRIC could be used to plan and manage an operational force's combat support system.

This report describes the Dyna-METRIC model from the logistician's perspective, with a minimum of mathematical detail. Thus the report should be useful to logisticians who may wish to use it either directly or indirectly, and its results should assist logistics policymakers in reaching decisions. While the report describes the essential procedural information needed by the "hands-on" analyst, it also describes the model's motivations and capabilities so that policymakers can evaluate Dyna-METRIC analyses in the light of other logistics information.

SUMMARY

Logisticians must plan, in peacetime, for wartime. Thus they must forecast both how the existing logistics system will perform in the more stressful wartime environment and what additional resources are needed to improve that performance.

This report describes a computer model, Dyna-METRIC, that can help the logistician to forecast future performance and identify wartime logistics constraints. The report discusses the model's general functional characteristics and capabilities, and a simple example is employed to demonstrate both the model's interfaces (input files and output reports) and its use in analysis, so that analysts can apply the model to specific problems.

LOGISTICS INFORMATION NEEDS

Air Force logisticians face a difficult planning and management task: assuring adequate logistics support for wartime needs in their peacetime decisions. They can manage peacetime support reactively, responding to periodic (e.g., weekly, quarterly) feedback on current force status, repair productivity, stockage effectiveness, and field exercise experiences. Unfortunately, they cannot wait for that feedback in wartime, because changes to the support system typically require long times to become effective. Rather, they must *forecast* the effectiveness of their peacetime decisions in the wartime environment.

A technique that merely assesses alternate logistics decisions would be inadequate for this task. Logisticians plan and manage support for hundreds of thousands of commodities and resources that jointly affect combat capability. Each of those commodities (e.g., fuel, munitions, test equipment, special vehicles, aircraft components) has unique support processes associated with it. Thus, if the forecasting technique does not provide some diagnostic hints about which commodities' support processes would most limit wartime capability, logisticians can only "work harder" to improve all support processes one by one--a nearly impossible task. They need information about which support processes will most likely limit future wartime combat capability.

INFORMATION PROVIDED BY DYNA-METRIC

The Dyna-METRIC model is a major step toward meeting these information needs. It provides five new kinds of information for logisticians charged with planning and managing support for aircraft components[1]:

1. Operational performance measures
2. Effects of wartime dynamics
3. Effects of repair capacity and priority repair
4. Problem detection and diagnosis
5. Assessments or requirements

The model provides operational performance measures that enable logisticians to see how all echelons' and functions' local resources and productivity (e.g., resource counts, production times) combine to affect overall weapon system support. The model incorporates dynamics for assessing how those echelons and functions would interact in the critical wartime environment, when external demands increase and the logistics system reorganizes to meet those demands. Further, the model forecasts how increased component demands would interact with available repair resources (test equipment and skilled personnel) and priority repair, so that logisticians can assess whether the available repair capability would be adequate to achieve the desired operational wartime capability. The model identifies and ranks problem components and support processes that cause excessive degradations to wartime capability, so attention and efforts can be focused on improving support for the most serious problems. Finally, the model can either assess existing resources and productivity or it can suggest a cost-effective mix of component spares to achieve a target wartime capability.

CAPABILITIES OF DYNA-METRIC

Dyna-METRIC is an analytic model that uses mathematical equations to forecast how logistics support processes would affect flying units'

[1]Flight-line support (e.g., refueling, munitions loading, and aircraft launching) is generally excluded from the model, as are personnel support (food, medicine, etc.) and ground-vehicle support.

capability in a dynamic wartime environment. Specifically, it forecasts the quantity of each aircraft component in repair and resupply throughout a wartime scenario, based on the component's unique interactions with the developing operational demands. It also combines these quantities probabilistically to estimate how all the aircraft components jointly might affect aircraft availability and combat sorties throughout the scenario. Because the model is analytic, it can (optionally) identify those problem parts that most limit aircraft availability, or it can suggest a cost-effective stock purchase to improve aircraft availability.

The central computation in the model is that of the expected number of components being processed by each function and echelon. Dyna-METRIC portrays component support processes as a network of pipelines through which aircraft components flow as they are repaired or replaced throughout a single theater. Each pipeline segment is characterized by a delay time that arriving components must spend in the pipeline before exiting the segment. Some delay times (e.g., local repair times) vary from component to component; others (e.g., intratheater transportation times) depend on the base being assessed. The expected number of components in each pipeline segment depends on the rate at which demands occur and the time components spend in each segment.

The sum of all pipeline segments is the key parameter for a probability distribution that specifies the probability that some number of components other than the expected number may exist in the pipeline network. The model expands each component's expected pipeline size into a complete probability distribution for the number of components currently undergoing repair and on order, so the probability distributions for all components can be combined to estimate aircraft availability and sorties.

The probability distributions are also important when the model computes requirements and identifies problem parts. When computing spares requirements, the program adds spare assets that will probably increase the number of available aircraft at minimal cost. When identifying problem parts, the model sequentially selects components based on the extent to which they will probably limit fully mission-capable (FMC) aircraft.

MODEL LIMITATIONS

No model ever mimics the real world exactly. Most models can represent accurately only a few of the more important features of the system being studied. Users must know a model's limitations so that they can determine the situations in which the model can be used confidently and those in which its results should be checked against other authoritative sources.

Dyna-METRIC's limitations are listed below:

1. Repair procedures and productivity are unconstrained and stationary except when repair capacities are explicitly stated.
2. Forecast sortie rates do not directly reflect flight-line resources and the daily employment plan.
3. Component failure rates vary only with flying intensity.
4. Aircraft within each base are assumed to be nearly interchangeable.
5. Repair decisions and actions occur only when testing is complete.
6. Component failure rates are not adjusted to reflect previous FMC sorties accomplished.
7. All echelons' component repair processes are identical.

Some capabilities were excluded from the model because they fell outside the realm of component repair. More often, capabilities were excluded because no one had yet solved the relevant problems mathematically. Continuing research is being done on at least two of those problems (constrained repair and sortie-dependent failure rates).

USING DYNA-METRIC: A SIMPLE EXAMPLE

To illustrate the use of Dyna-METRIC, we consider the example of a single aircraft squadron deploying to a single base. The aircraft are extremely simple, composed of only ten major components that have no subcomponents. This problem does not stress the model's ultimate limits, but it does illustrate most of Dyna-METRIC's major functions.

In our hypothetical wartime scenario, the squadron consists of 24 aircraft that deploy to a bare base. Upon arriving, the unit plans to fly three sorties per aircraft per day for the first seven days and one sortie per aircraft per day thereafter. Adequate filler aircraft exist to assure that the unit will be maintained at full strength throughout the first 30 days of the deployment.

The unit's detailed deployment plans call for spare parts and flight-line personnel to be deployed on the same day as the aircraft, so that line-replaceable units can be removed and replaced immediately. However, limited transportation capacity will delay the deployment of intermediate-level maintenance to repair those removed components until five days after the aircraft are deployed. Based on previous experience, it is estimated that an additional two days will be required to set up the intermediate maintenance facility before repair can start on any failed component.

Because the war plan is extremely limited (only one squadron deployed), adequate transportation resources will exist to provide parts resupply from the CONUS throughout the deployment. Thus the unit will continue to receive requisitioned spares from depot repair.

The Dyna-METRIC reports for this problem indicate that seven to eleven aircraft will not be fully mission capable by day 7 of the scenario, and two of the ten components most limit capability on that day, primarily because component repair has not yet begun. Obviously, that performance could be improved by simply buying more stock, but it could also be improved by deploying repair capability earlier. Additional Dyna-METRIC analyses could determine how much stock to buy or how early repair would need to arrive to achieve satisfactory performance.

CONTENTS

FIGURES

ACRONYMS

ATE (automatic test equipment): a test station (often computerized) that automatically diagnoses the causes of component failures and indicates potentially effective repair actions.

AWP (awaiting parts): a repair status indicating that a component's repair cannot continue until one or more serviceable subcomponents become available.

BLSS (base-level self-sufficiency spares): a nondeployable set of wartime spare components held in reserve for wartime needs.

CIRF (centralized intermediate repair facility): a shop that repairs components from one or more remote bases; components removed at some bases ncounter transportation delays before and after the repair proc...

FCFS (first come, first served).

FMC (fully mission capable): an aircraft status indicating that the weapon system can accomplish any of its intended wartime missions.

ILM (intermediate-level maintenance): a field activity or facility that performs limited component repairs; includes repair shops on bases and CIRFs.

LRU (line-replaceable unit): a component typically removed from the aircraft at the flight line, rather than in a back shop.

MDS (mission design series): a specific aircraft design (including possible mission-dependent design extensions) that implies a specific configuration of components.

NFMC (not fully mission capable): an aircraft status indicating that the weapon system's ability to accomplish at least one wartime mission has been degraded.

NMC (not mission capable): an aircraft status indicating that the weapon platform cannot accomplish any wartime mission.

NRTS (not repairable this station): a decision or status indicating that a component cannot be repaired by a specified facility.

OST (order and ship time): the time required to initiate a component requisition at the base, fill that requisition at the depot, transport the component to the base, and enter the component into base supply.

PMC (partially mission capable): an aircraft status indicating that the weapon system can perform at least one wartime mission, though perhaps in a degraded mode.

QPA (quantity per application): the number of components (or subcomponents) physically mounted on an aircraft (or another component).

RCT (repair cycle time): the average time required to schedule, diagnose, repair, and recertify the operation of a reparable component.

RR (remove and replace): a repair policy designating that a specific component cannot be repaired at the ILM facility, usually for some significant period after a unit deploys with only limited component maintenance capability.

RRR (remove, repair, and replace): a repair policy designating that a specific component can be repaired at the ILM facility, once initial limited component maintenance capability has been deployed and set up.

SRU (shop-replaceable unit): a subcomponent of an LRU that is typically removed from the LRU in the shop, rather than from the aircraft at the flight line.

WRM (war reserve material): consumable and nonconsumable material acquired and stored in peacetime for use during wartime; includes WRSKs for deploying units and BLSS for units that will fight in place.

WRSK (war reserve spares kit): a deployable set of spare components held in reserve for wartime needs.

I. INTRODUCTION

Air Force logisticians face a difficult planning and management task: assuring adequate logistics support for wartime needs in their peacetime decisions. In peacetime, they can manage support reactively, responding to periodic (e.g., weekly, quarterly) feedback on current force status, repair productivity, stockage effectiveness, and field exercise experiences. Unfortunately, they cannot wait for that feedback in wartime, because changes to the support system typically require long times to become effective. Rather, they must forecast the effectiveness of their peacetime decisions in a wartime environment. That is especially difficult, because both flying demands and support-system operations change dramatically in wartime, when flying increases and support resources redeploy. Without information on the effects of current or alternative support policies and decisions on combat forces' wartime capability, logisticians cannot assure that their ultimate wartime objectives will be met. Thus, they need forecasting techniques that will enable them to construct and assess alternative logistics resource mixes, policies, and procedures in future wartime environments.

A technique that merely assesses alternative logistics decisions would be inadequate. Logisticians plan and manage support for hundreds of thousands of commodities and resources that jointly affect combat capability. Each of those commodities (e.g., fuel, munitions, test equipment, special vehicles, aircraft components) has unique support processes associated with it. Thus, if the forecasting technique does not provide some diagnostic hints about which commodities' support processes will most limit wartime capability, logisticians can only "work harder" to improve all those processes simultaneously--a nearly impossible task.

The Dyna-METRIC model predicts how alternative component support processes and resources will affect a theaterwide force's combat capability, given the wartime operations and logistics plans. In contrast to previous models of wartime component support that emphasize noncombat measures such as component backorders, Dyna-METRIC analytically forecasts how component support resources, plans, and process times will affect overall force capability, measured in fully mission capable (FMC) aircraft or FMC sorties. It also identifies those components whose support processes prevent achieving the desired level of FMC aircraft, or whose purchase would cost-effectively achieve that goal. The model focuses primarily on those support processes that affect aircraft components and their contribution to aircraft wartime capability. Flight-line support (e.g., refueling, munition loading, and aircraft launching) is generally excluded from the model, as are personnel support (food, medicine, etc.) and ground-vehicle support.

This report describes one implementation of Dyna-METRIC[1] in non-mathematical terms to provide practical knowledge of the model's capabilities for managers and policymakers.[2] Section II outlines the kinds of new information the model can provide. Section III describes the model's capabilities in some detail. Section IV describes the model's use through a simple example which should help new users overcome many of the learning difficulties often associated with a new model.

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[1] Version 3.04, which incorporates capabilities drawn from several previous versions developed to support special studies, both at Rand and in the Air Force. Future versions will extend those basic capabilities as needed to meet research and management information system requirements.

[2] The underlying mathematics are described in Hillestad and Carrillo (1980); and Hillestad (1982).

II. MOTIVATIONS FOR THE DEVELOPMENT OF DYNA-METRIC

Logisticians already maintain and use numerous computer models to help plan logistics support. Why on earth would they need yet another model? There is always a need for models that provide new information to better assure adequate support. Dyna-METRIC was designed to provide five new kinds of information to support logistics decisionmaking:

1. Operational performance measures
2. Effects of wartime dynamics
3. Effects of repair capacity and priority repair
4. Problem detection and diagnosis
5. Assessments or requirements

Taken together, this new information should improve logisticians' abilities to evaluate current and future logistics support in a changing environment with limited resources, to develop and manage workaround and get-well plans, and to widen the range of alternatives considered in those plans.

OPERATIONAL PERFORMANCE MEASURES

Currently, the performance of the USAF logistics support system is measured in three dimensions:

1. Resource counts (shelf stock, war reserve materials (WRM) percent filled, etc.)
2. Process delay times (repair time, order and ship time, etc.)
3. Peacetime customer satisfaction proxies (percent requisitions filled from shelf stock, not-mission-capable (NMC) aircraft, cannibalization rates, etc.)

Each of these measures is correlated to overall support for USAF weapons systems, but they do not enable logisticians to perform an integrated assessment of overall support or of the relative importance of various support shortfalls.

Dyna-METRIC uses detailed resource counts and process delay times to forecast how these factors would affect the capability of weapons systems. That is, it integrates two of the traditional performance measures to relate them to the key USAF objectives of aircraft availability and FMC sorties flown. Most important, it assesses those measures in the stressful, dynamic *wartime* environment.[1]

EFFECTS OF WARTIME DYNAMICS

In wartime, everything changes. Not only do operational demands for aircraft increase, but many aircraft squadrons redeploy from their peacetime training posture to new bases. The logistics system must change to support that redeployed, more active force. Base-level repair facilities must be redeployed, resupply (i.e., depot repair, distribution, and transportation) must be reestablished, and component stocks must be redeployed, all when the existing strategic transportation resources may be highly stressed deploying ground and air units, food, munitions, fuel, medicine, and other resources necessary to support the engaged forces.

Logistics support disruptions may occur in the early days of a conflict, while the necessary logistics resources are being reestablished and reconfigured to support the wartime forces. Dyna-METRIC models these disruptions and their dynamic effects on weapons systems wartime capabilities. Thus, the model can be used to forecast logistics-system performance in a wartime environment that cannot be routinely experienced in practice.

EFFECTS OF REPAIR CAPACITY AND PRIORITY REPAIR

Most logistics support models ignore constrained repair issues. Such an omission implicitly assumes either that "ample" repair resources exist (or will be deployed) to eliminate queueing or that the frequency of repair demands will not change substantially. If either condition

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[1] Some argue that the peacetime logistics system is also dynamic and that a need also exists to forecast peacetime performance. Muckstadt (1980) described some of those dynamics, and Scalf and Tripp (1981) described the use of Dyna-METRIC to assess the support needs of the growing F-16 force.

held, the total repair process delay time (including queueing delays) would remain constant.

But neither of these conditions is likely to hold true in wartime. Flying activity levels will increase dramatically in wartime, necessitating additional component removals, which may exacerbate the queueing delays that almost always exist for repair resources.

Wartime increases in available repair resources and their productivity may partially offset the increased demands due to higher activity levels. Overtime work could increase the available repair resources (technicians, equipment, and tools), and additional repair resources from colocating deploying units also may offset demands. The productivity of the repair system can also change in wartime. Improved morale in wartime may increase technicians' efficiency, and colocated automatic test equipment (ATE) may enable rapid cross-checks of the system's diagnosis and functionality, as well as cannibalization of failed or marginal ATE components.

But available repair resources and their productivity may also decrease in wartime: Base attack may destroy or damage repair resources; resupply cutoffs may prevent repair of test equipment; and fatigue may progressively degrade technicians' productivity.

Unless these dynamic changes are evaluated together, it cannot be assured that repair capacity limits will not interact with stock availabilities to further degrade wartime aircraft availability. Traditional models' assumptions (e.g., that "ample" repair capacity will exist) do not assess these interactions and their effects on aircraft availability.

Moreover, traditional models implicitly assume that the repair system is insensitive to the state of the operational forces. They represent the repair system as a first come, first served (FCFS) process that does not expedite repair for the component most needed by the operational force. In fact, repair managers habitually reallocate their repair resources to assure that those components that most degrade aircraft availability are repaired first. Thus, traditional models do not reflect how responsive repair management can mitigate against component shortfalls due to constrained repair.

Dyna-METRIC provides a user-selected capability to model the effects of both repair constraints and priority repair management. Components can be assigned to specific repair resources (such as repair teams or ATE stations), and the time-varying quantity of those repair resources can be specified. Using the associated components' failure rates and hands-on repair times, the model estimates which components each repair resource would repair if it were continually reallocated to those that most limit available aircraft.

As a special feature, the model's constrained repair/priority management capability provides an explicit capability to represent ATE. When ATE is modeled, the user can represent the increased availability of colocated ATE. The model can also cannibalize ATE backorders into a single stand and can allow the resulting partially mission-capable (PMC) stand to repair some (but not all) components.

PROBLEM DETECTION AND DIAGNOSIS

Evaluating how the logistics system would affect wartime aircraft availability and sorties is an important step toward helping logisticians plan and manage wartime support. But it is not enough. The logistics system is large, geographically dispersed, and composed of many distinct, interacting elements. Simply indicating that the whole system does not provide the desired level of wartime support does not identify which part of that system most limits that support. Without an ability to detect and diagnose logistics problems, logisticians can only keep their fingers crossed, try harder, or buy out the problem. The ability to detect and diagnose logistics support problems would allow them to focus their efforts more narrowly on those few components and associated support processes that most limit aircraft availability.

Dyna-METRIC is an analytic model, composed of a relatively small set of mathematical equations that can be manipulated to solve for more than one unknown quantity. The model can both assess how the various components' support processes contribute to wartime aircraft availability and sorties and identify those components whose support falls short compared to a user-stated goal.

The model identifies the components that prohibit achieving a given aircraft availability goal. Further, it ranks those components on the basis of their likely effect on aircraft availability. Finally, it reports the distribution of reparable and serviceable assets throughout the logistics system, so that analysts can identify the portions of the support system that contribute to any shortfall and rapidly determine changes to the system that might improve support.

ASSESSMENTS AND REQUIREMENTS

In addition to computing how given resource levels and process times would contribute to wartime capability, Dyna-METRIC exploits the mathematical structure of its underlying equations to suggest alternative cost-effective repair or stockage resource purchases that would achieve a target aircraft availability goal throughout the wartime scenario. By comparing alternative repair/stockage resource packages, logistics planners can quickly identify the most cost-effective way to achieve their goals.

In summary, Dyna-METRIC provides important new information to support logisticians' decisionmaking. It relates planned or current logistics support to wartime operational capability, considers wartime dynamics, reflects constrained repair and priority management, detects and diagnoses component support problems, and suggests cost-effective support packages to meet wartime requirements.

The next section describes the model's operation in a non-mathematical way, indicating what the model does and what it does not do.

III. CAPABILITIES OF DYNA-METRIC

Dyna-METRIC is an analytic model that uses mathematical equations to forecast how logistics support processes would affect flying units' capability in a dynamic wartime environment. Specifically, it forecasts the quantity of each aircraft component in repair and resupply pipelines throughout a wartime scenario, based on the component's unique interactions with the developing operational demands. It also combines these pipeline quantities probabilistically to estimate how all the aircraft components jointly might affect aircraft availability and combat sorties throughout the scenario. Because the model is analytic, it can (optionally) identify those problem parts most limiting aircraft availability, or it can suggest a cost-effective stock purchase to improve aircraft availability.

This section describes the model's capabilities, excluding most of the mathematical details. It describes the logistics support system (as it pertains to components) rather than the model's internal processes. This description should enable logistics analysts to determine whether Dyna-METRIC can represent their specific problem. The four key capabilities of Dyna-METRIC are:

1. Forecasting component pipelines
2. Estimating aircraft availability and sorties
3. Identifying problem parts
4. Suggesting cost-effective stock purchases

After a brief overview of these capabilities, we will describe each in detail. Dyna-METRIC, like all models, makes assumptions about the real world. We conclude with a description of limitations that grow out of the assumptions used in Dyna-METRIC.

A COMPUTATIONAL OVERVIEW: PIPELINES, AIRCRAFT AVAILABILITY, SORTIES, PROBLEM PARTS, AND STOCKAGE

Dyna-METRIC portrays component support processes as a network of pipelines through which aircraft components flow as they are repaired or replaced. Figure 1 represents each of these processes as an arc which may be conceived as a segment of a pipeline containing components flowing in the direction indicated by the arrow. Each pipeline segment is characterized by a (random or deterministic) delay time that arriving components must spend in the pipeline before exiting the segment. Some delay times (e.g., local repair times) vary from component to component; others (e.g., intratheater transportation times) depend on the base being assessed.

As shown in Fig. 1, failed components enter the pipeline network at aircraft bases' flight lines. Each base has several aircraft whose use generates particular operational demands for components. Further, each has a flight-line support capability that removes and replaces those components, drawing from local supply as needed.

Each base may also have local repair shops to repair failed components. For units deploying to new bases, that repair capability may be available only after some delay, while the repair facility is being deployed and set up. Once components have been removed from aircraft, they are either repaired at the local shops or sent to other repair facilities. If the component can be repaired locally, it is returned to local stock; otherwise, it is declared "not reparable this station" (NRTS) and is sent to either a centralized intermediate repair facility (CIRF) or a depot. When a component is declared NRTS, a replacement is immediately requisitioned from the facility that will receive it, and that facility immediately sends the base a serviceable spare, if one is available. If none is available, the CIRF will send one to the base as soon as possible (after all prior requisitions have been filled). Once the reparable component reaches the CIRF, it is repaired and returned to CIRF stock, so that it can be issued to satisfy the next demand.

If the CIRF cannot perform the repair, the component is sent to the depot, either directly from the base (if the CIRF does not have the required repair capability) or from the CIRF (if the CIRF attempted to

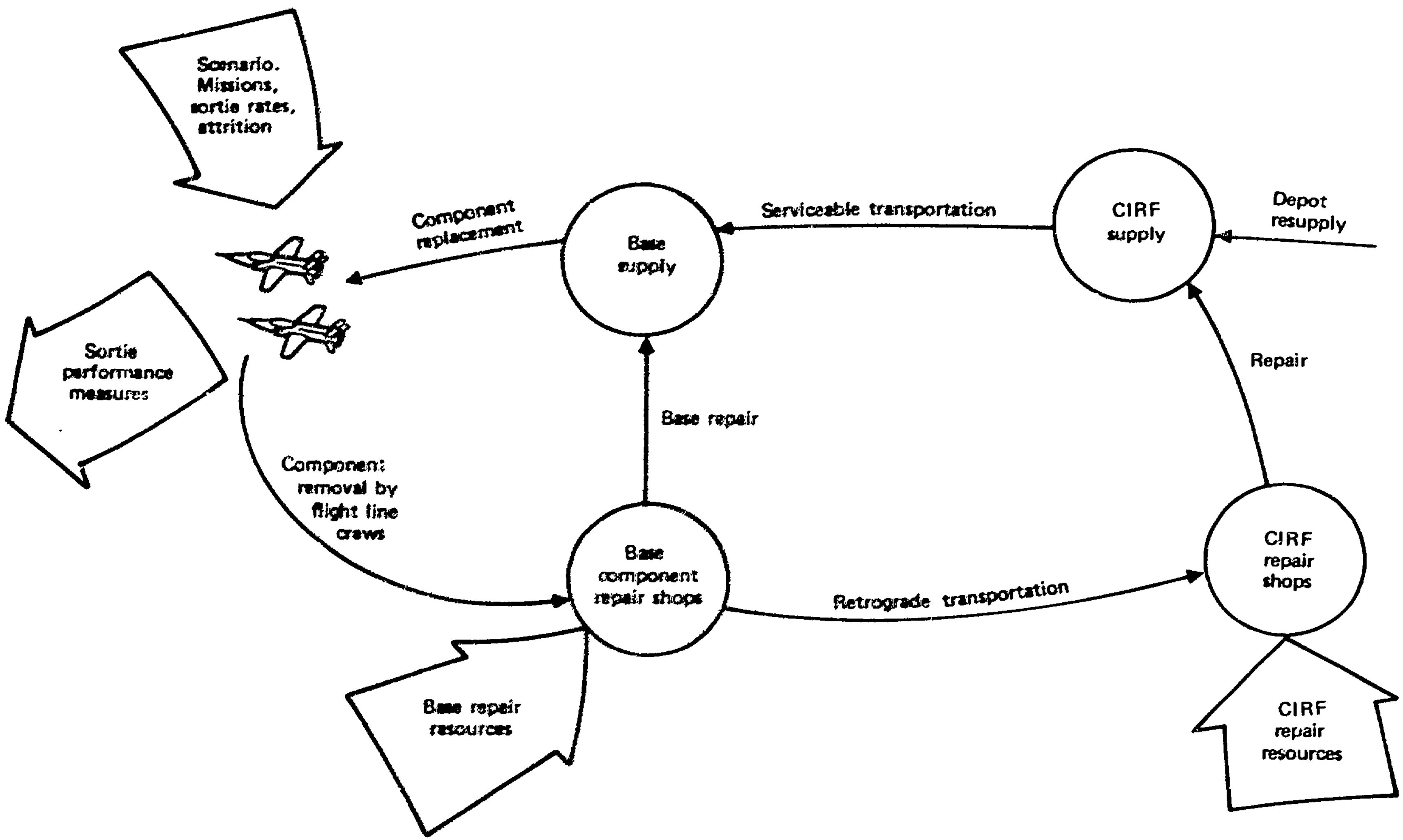

Fig. 1 -- Aircraft logistics support network

repair the component but failed). In either case, a replacement component is immediately ordered from the depot and shipped to the requisitioning facility (base or CIRF).[1]

The key equation in Dyna-METRIC computes each aircraft component's *expected pipeline size*, or the number of each component that should be expected in each segment of the pipeline network (base repair, base-to-CIRF transportation, CIRF repair, CIRF-to-base repair, or on order from the depot). The computation is based on the planned time-dependent aircraft flying activity, the flying-dependent removals caused by that activity, the time-dependent availability and delays associated with transportation and repair at the base and the CIRF, the likelihood the component will be NRTS at the base and the CIRF, and the depot resupply time. The model totals the component pipeline segments to forecast the total pipeline size (i.e., the expected quantity on order and in local repair) as seen by each base.

The expected total pipeline size is the key parameter for a probability distribution that specifies the probability that some number of components other than the expected number may exist in the pipeline network (Hillestad and Carrillo, 1980; Hillestad, 1982). Using user-specified parameters, the model expands each component's expected pipeline size into a complete probability distribution for the number of components currently undergoing repair and on order at a base or CIRF.

If the operational demands and the logistics system's characteristics were constant over time, the estimation of the expected pipeline quantity and the probability distribution would be relatively easy. Assuming that individual component removals are independent of each other (i.e., assuming that removing one component neither causes nor prevents the removal of another), Palm (1938) demonstrated that the pipeline quantity takes on a Poisson probability distribution whose mean is the product of the average failure rate and the average repair time. Literally, the steady-state expected pipeline quantity could be estimated by simply multiplying two numbers together.

[1] This represents a simplification of the real-world process, because the depot will probably repair the component and return it to depot stock. Future versions of Dyna-METRIC will model the depot repair and stockage functions explicitly.

Unfortunately, operations and logistics seldom achieve steady-state, especially in wartime. Not only do the operational demands change in wartime, but the logistics system restructures itself, redeploying stock, redeploying repair equipment and personnel, and reallocating transportation over time. Thus, the relatively simple steady-state equations cannot accurately forecast pipeline quantities in a dynamic wartime scenario.

Hillestad and Carrillo (1980) demonstrated how Palm's result could be extended to the dynamic wartime situation. In their formulation (Fig. 2), the time-dependent component removals due to operational demands (e.g., daily demands over some time) are combined with the time-dependent repair capability (e.g., the probability that an item removed at time t will still be in repair at a later time s) to estimate the expected pipeline quantity over time. They also extended Palm's original result to show that the pipeline distribution would be Poisson--even under conditions of time-varying demands and repair. While the Hillestad-Carrillo result is slightly more complicated than Palm's simpler steady-state result, it can be easily computed on a modern digital computer. As shown in Fig. 2, Dyna-METRIC combines each component's dynamic demands and repair process times to estimate the expected pipeline quantity for each pipeline segment; it adds all the pipeline segments to estimate the total pipeline seen by each base; and it computes the (typically Poisson)[2] probability that a given number of components are in repair and on order at each base.

Using the total pipeline probability distributions and the available stock at each location, the model next forecasts how the components in repair and on order would (probabilistically) generate backorders (or aircraft "holes") for each component at a given time, as shown in Fig. 3. It then distributes those holes across aircraft for two alternative cannibalization policies: no cannibalization and full cannibalization. For no cannibalization, the model assumes that failed components occur randomly across the aircraft at each base. For full

[2] Important extensions have been incorporated in the model for those cases in which component removals are not independent. These permit the user to model uncertainty about the failure rate, the clustering of demands, or the flying-hour removal policies.

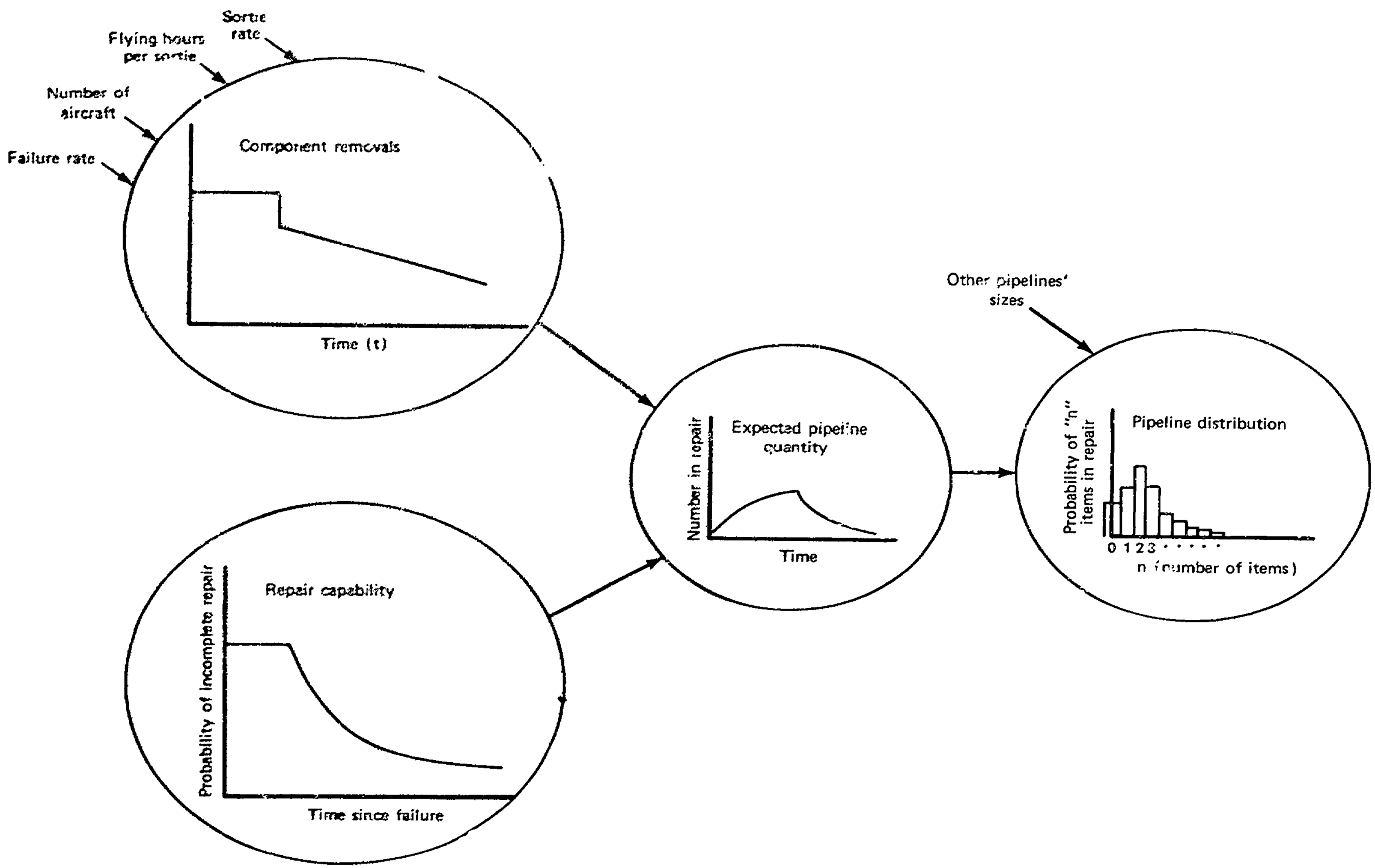

Fig. 2 -- Computing pipelines

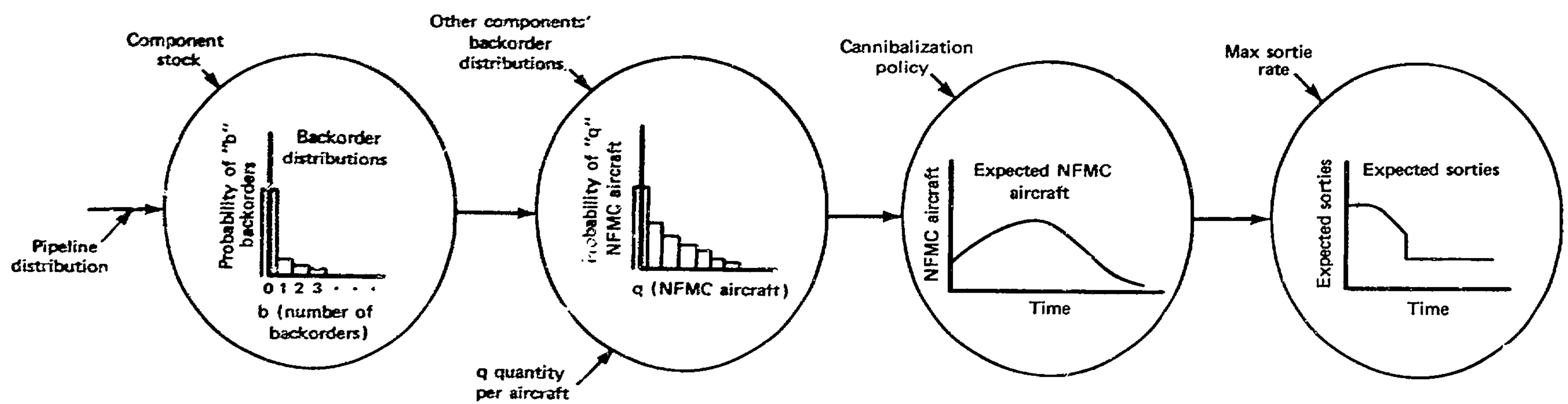

Fig. 3 -- Computing backorders, NFMC aircraft, and FMC sorties

cannibalization, it assumes that all component "holes" at each base are quickly consolidated on the fewest possible aircraft, thus making as many aircraft as possible FMC. (The aircraft with "holes" are not fully mission capable (NFMC).) Means and standard deviations are computed for both cannibalization policies, but a complete degraded aircraft probability distribution is computed for full cannibalization. Finally, the model uses the base flight lines' maximum abilities to produce sorties from FMC aircraft to forecast the number of FMC sorties, assuming full cannibalization.

The probability distributions are especially important when the model computes requirements and identifies problem parts. It uses the overall NFMC aircraft probabilities and the component backorder probabilities to evaluate how each component's stock would affect overall FMC aircraft (assuming full cannibalization). When computing spares requirements, the program adds spare assets that will increase FMC aircraft at minimal cost. When identifying problem parts, the program sequentially selects components based on the extent to which they limit FMC aircraft.

FORECASTING COMPONENT PIPELINES

At its core, the model solves a single integral equation to forecast the expected number of each aircraft component in each pipeline segment at any user-specified time of analysis. To achieve that goal, it first computes two intermediate quantities for each segment for each day in the scenario through the time of analysis: component arrivals and a component delay function. Ultimately, the base-by-base flying demands (a function of assigned aircraft, attrition, daily sortie rate, and sortie duration) and component demand data (flying-hour failure rate, quantity per aircraft, and percent application) drive the rate at which components arrive at each pipeline segment. But one segment's time delays may cause another segment's arrivals to be delayed, if a component must pass through one segment before entering another. Those time delays are represented as the probability that an arrival on each day of a time-dependent scenario would still remain in the segment at some later time of analysis. A high delay probability (i.e., near 1.0) would mean that a part arriving on a given day probably still remains in the segment, while a low delay probability (near 0.0) would mean that such a part has probably departed one segment and entered another (or been returned to stock). These two intermediate quantities are computed for each day prior to the time of analysis, then multiplied together and summed over time to forecast the total expected components still remaining in the pipeline segment.

For example, the model might compute the expected quantity of an item in local repair in a scenario. First, it would compute the expected daily component failures and the repair delay probabilities. The daily demands for repair would depend on the base-level flying program and the component's flying-related failure rate. Let us assume one base with a wartime sortie program that calls for 500 daily flying hours for the first 20 days and 100 daily flying hours thereafter (e.g., 100 aircraft, no attrition, 1-hour sorties, and sortie rates of five per aircraft before day 21 and one per aircraft thereafter). Further, let's assume the item has a 0.01 probability of failure per flying hour. Dyna-METRIC would predict that we should expect five component failures each day for the first 20 days and one failure daily thereafter, as shown by the solid line in Fig. 4.

The repair delay probabilities would depend on the characteristics of the repair process. Dyna-METRIC supports either a deterministic (fixed) or random (exponentially distributed) repair time. To keep our example simple, let's assume that the repair process is deterministic and that a repair always takes exactly four days. The model computes the repair delay probability to be 1.0 for any component arriving in the four days prior to the time of analysis, and 0.0 otherwise. This means that all component failures during the four days before the time of analysis would still be in repair, but that all prior failures would have already been repaired.

Finally, the model uses these two functions (expected daily demands and time-dependent repair-delay probabilities) to determine the expected number of items still in repair at the end of a given day, say day 23. For all days through day 19, the repair delay function is zero, so only failures on days 20, 21, 22, and 23 would still be in repair. Because no components that failed on those four days have finished repair, there

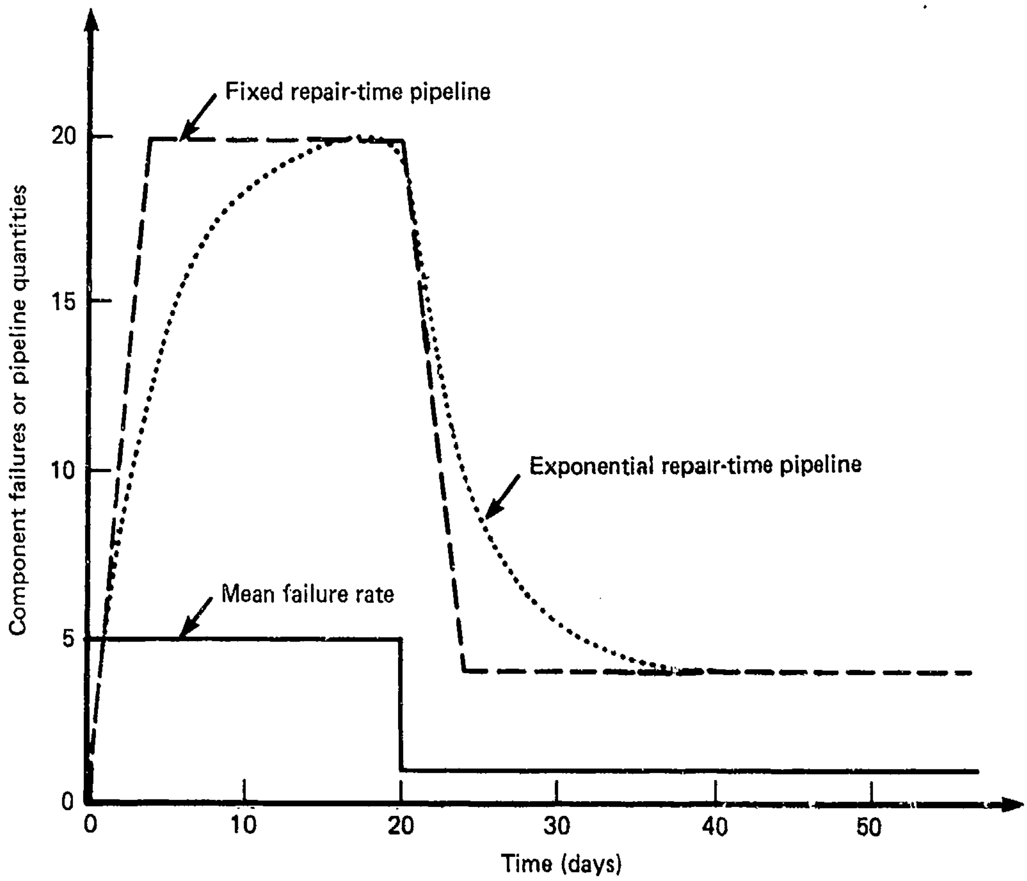

Fig. 4 -- Illustrative computation of repair pipeline

should be

$$\underset{\text{Day 20}}{5 \times 1} + \underset{\text{Day 21}}{1 \times 1} + \underset{\text{Day 22}}{1 \times 1} + \underset{\text{Day 23}}{1 \times 1} = \underset{\text{Total}}{8}$$

items still in repair. If the local repair pipelines were computed daily from day 0 to day 55, fixed repair times would yield the dynamic local repair pipeline response over time shown by the dashed line in Fig. 4.

For comparison, exponential repair times with the same mean would yield a dynamic response shown by the dotted line in the same figure. Note that the exponential repair times tend to dampen the pipeline dynamics because some failed components are repaired well before the average repair time (as often happens in the real world).

Failures on day 23 are included in the items still in local repair on that day. Had any day 23 failures been repaired (i.e., had the repair delay function for day 23 been less than 1.0), those repairs would not have been included as items still in the local repair pipeline. Thus, the model's time of analysis actually corresponds to the *end* of the day specified by the user.

"Nonlinear" Demand Patterns: How Demands May Change from Peace to War

Some components' demand patterns may depend on factors other than the aircraft flying hours assumed by the model. Often demand patterns will change if there is some basic change in the operators' usage patterns in wartime. For example, aircraft guns are used on only a small fraction of the total peacetime training sorties, but they might be used on a much larger fraction of wartime sorties. Thus the per-sortie (or per-flying-hour) usage of gun barrels would increase dramatically in wartime.

Some components' failure rates, on the other hand, may decrease in wartime. An item like a radar transponder may be essential in peacetim to increase training safety, but it might be unnecessary (or even dangerous) in wartime. Thus, its per-sortie usage might drop.

The model incorporates a "nonlinearity factor"[3] for each component so that users can specify how flying-hour failure rates increase (or decrease) in wartime. The factor is expressed as a ratio between wartime and peacetime use. To double the wartime per-sortie usage, the factor would be set to 2.00. To halve the wartime per-sortie usage, it would be set to 0.50.

Generally, only limited data (or models) are available to forecast how the per-sortie usage of a given component may change in wartime. Thus, most users set most components' nonlinearity factor to 1.00.

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[3] Strictly speaking, this factor is misnamed. Even when the factor is something other than 1.00, wartime removals still depend linearly on flying hours. We have retained this name in deference to common usage and tradition in the Air Force logistics community.

Echeloned Support Processes: How Off-Base Support Activities Affect Total Component Pipelines

Some significant fraction of a component's support usually comes from off-base support activities such as off-base repair, transportation (of both reparable and serviceable components), and depot or CIRF supply. These activities can be represented in one of two ways in Dyna-METRIC: as a simple order and ship time (OST) delay when a component is requisitioned from a depot, or as an explicit second-echelon repair and supply process with transportation delays to and from a CIRF.

Some analyses can proceed effectively by treating all of the off-base pipelines as a single expected resupply time for each component. In those analyses, the components found to be NRTS would encounter an OST delay after attempted repair had failed at a base. Thus, the model would delay the demands for the OST pipeline by the component's base-level repair time (to allow for diagnosis and attempted repair delays at the base) and would then use those delayed demands in conjunction with the (component-dependent) OST delays to compute the expected number of each component on requisition.

To forecast how dynamic variations in some higher echelon's repair and resupply processes will affect base-level wartime capability, the second-echelon processes can be modeled explicitly in Dyna-METRIC by indicating which bases are connected to each second-echelon facility (e.g., each CIRF).[4] The component stock levels at each base and CIRF, and the serviceable- and reparable-component transportation times (i.e., times required to transport serviceable components from a CIRF to a base and vice versa). The model delays the arrival of failed components at each CIRF by the base repair times and the reparable-component transportation times. Just as with the base repair pipeline segment computation, the delayed arrival rates are used with the CIRF's repair delays to forecast how many items are in the CIRF repair pipeline segment.

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[4] Failed (reparable) components are transported from a base to a higher repair echelon, such as a CIRF or depot. Repaired (serviceable) components are transported the other way. In general, the delay times are different for each transportation process.

To translate the CIRF repair and resupply processes into an effect on each base's serviceable stock, the model assumes that the base would requisition a replacement component from the second-echelon stock at the same time the failed component was declared NRTS. Thus, a serviceable component would be drawn from the appropriate CIRF's stock (if available) and shipped immediately, so that the base would receive it after a specified serviceable-component transportation time. If a requisitioned component were not available from stock, the requisition would be filled (on a first come, first served basis) only when sufficient components had completed CIRF repair. In either case, the off-base pipeline includes all items ordered but not yet received by the base (i.e., both serviceable components in transit and CIRF backorders not available from CIRF stock).

To facilitate three-echelon component support analyses, the model allows the CIRF to requisition replacements from a depot with an OST delay. This capability operates just like the OST delays from the base level, except that the CIRF's demands are delayed to include transportation delays and CIRF repair times.

Whether the simple base-level model or the more complex two-echelon model is used, Dyna-METRIC adds the number of components in the on-base pipeline to the number in the off-base pipeline to estimate the total expected number of components in repair or on order at the base.

Pipeline Flow Constraints: How Repair Resource Limitations Affect Pipeline Quantities

If there were always ample repair resources (e.g., test equipment, facilities, and personnel) to serve every pipeline segment, components would always be repaired within the hands-on test times. But repair resources are expensive, so they are usually limited in quantity. Thus, repair resources that are ample for peacetime may be inadequate for wartime, when increased wartime flying demands cause increased component failures. Therefore, logisticians would like to forecast how those repair resource limitations might affect wartime capability.

Dyna-METRIC provides a first approximation for this problem. The approximation, originally designed for base-level ATE that test and diagnose several different components (one at a time), can be employed to assess any simple shop or repair process whose capacity is limited by only one resource type. Thus it can also be used to model how technicians, repair teams, test stands, or other facilities may limit repair productivity.

Dyna-METRIC uses a mean-value simulation to estimate how many of each component are being tested or are awaiting test at each base or CIRF. The simulation assumes that repairing a component at a base or CIRF requires access to a key repair resource (nominally, a test stand, but perhaps some other critical, limited repair resource such as a test team) for the hands-on repair period, including initial test, diagnosis, module replacement, and retest. If the component's failure rates temporarily exceed the test stand's capacities, arriving components may not be able to enter repair immediately and a repair backlog may arise. The size of that backlog (and its rate of increase) depends on the time-varying arrival rate of reparable components, the hands-on test-stand time needed to repair each component, and the number of test stands able to repair the components.

Not all test stands (or repair teams) can repair every component. Generally, skill limitations, organizational arrangements, or equipment design limit the range of components that a particular test-stand type can repair. In Dyna-METRIC, each test-stand type can repair only a user-specified list of components, and each component can be assigned to only one test-stand type.

A given repair facility may have several test stands of a given type. For example, it may have five engine-repair teams, three radar hot mockups, etc. In Dyna-METRIC, the number of each test-stand type can be specified over time, as additional repair facilities are deployed throughout the scenario. Thus, the user can analyze the interaction between the time-varying removals and the time-varying repair capacity.

Unfortunately, test stands cannot be devoted solely to repairing components. Often, they themselves need testing and repair, which reduces their availability for component repair. (Human test teams cannot be continually available either--they get sick, take leave, sleep, etc.) In the case of ATE, increasing the number of colocated test stands may increase the availability of each, because operators can quickly cross-check one stand's results against another's and can interchange test-stand components to isolate failures. Dyna-METRIC adjusts the daily test time available on each test-stand type, according to user-specified tables and the number of colocated test stands.

Test stands also fail, particularly ATE, which is usually composed of many interdependent parts. When such a failure occurs, repair facilities typically isolate the problem and replace the failed component, if a replacement is available. If a replacement component is not available, it may still be possible to use the ATE to repair some aircraft components while the failed ATE component is repaired or reordered. In that case, the ATE is only partially mission capable (PMC). If only one ATE component is in repair or on order, only one ATE test stand can be PMC. If more than one ATE component is in repair or on order, the ATE operators may choose to consolidate the failed components (i.e., cannibalize them) into a single PMC test stand to maximize repair throughput and minimize test ambiguities. Dyna-METRIC consolidates failed ATE components into a single test stand, and it degrades the PMC test stand's ability to repair aircraft components, depending on user-specified probabilities of repair capability and the rate of test-stand backorders.

One important wartime logistics objective is to maximize the number of FMC aircraft available to the operational forces. Repair processes can help increase the number of FMC aircraft at any time by working first on those components that are degrading the most aircraft. Especially in wartime, logistics management adjusts repair priorities to increase work on those aircraft components that cause the most NFMC aircraft. Dyna-METRIC dynamically reassigns repair priority for each test-stand type throughout the scenario, so that those components that cause the most NFMC aircraft are repaired first.

Once the available daily test time is computed (based on the number of test stands and the availability factors entered by the user), the model adds the daily computed demands for each component to its current workload (if any), allocates the available test time to components (based on the number of NFMC aircraft caused by each), and subtracts repaired components from the remaining workload, based on that allocation. The remaining workload for each component is used as the repair pipeline (at the base or CIRF) in subsequent computations. Thus, the simulation's estimate of remaining workload is used in lieu of the repair pipeline segment in Fig. 1.

Peacetime Demands and Pipelines: "Warming Up" the Model

The dynamic equations compute only the pipeline contributions due to flying activities during the analysis period. If a unit had prior flying activity, its pipelines would not initially be zero. Thus many analyses require that the component pipelines be "warmed up," or filled with components based on prior activity. Three alternative techniques are available to warm up the model's pipelines: static initialization, dynamic initialization, and dynamic bootstrapping.

The static initialization considers a steady-state flying program at each base prior to the scenario. Based on that flying program and the peacetime repair and resupply delay times, the model initializes several "peacetime" pipelines that empty as the scenario proceeds. When war breaks out, the components on order from the depot may not arrive immediately, because available transportation will be diverted to other priorities. Those peacetime pipelines and the assets they contain may be cut off--both in the real world and in Dyna-METRIC.

Often, the peacetime flying and support activities leading up to a wartime scenario are not static. Those flying activities should be expressly modeled, so that the model's pipeline segments will reflect dynamic peacetime activities prior to the wartime activities.

Finally, the dynamics may be so dramatic or so extended that a single model run cannot accommodate the combined peacetime and wartime scenarios.[5] In that case, the model has the capability to save its pipeline segments at the end of one run and use the data to initialize itself at the beginning of the next run. Using that facility, it is possible to "bootstrap" one dynamic analysis on the end of another.

[5] The maximum duration of a single run can be controlled when the model is compiled. Most analysts use a 30-day limit, though other values may be selected.

How Subcomponents Affect Component Pipelines

Aircraft components are typically constructed from several subcomponents, each with its own demand, repair, and resupply processes. In the model, those subcomponents flow through their own networks of support pipelines, and pipeline quantities are computed for each, just like components. Unlike components, the subcomponents' demands are delayed by the component repair process delays, to permit time to diagnose the component failure before demanding the subcomponent needed for the repairs.

Subcomponents' demand and support functions do not directly affect aircraft availability, but they do affect components' availabilities, which in turn affects aircraft availability. If a subcomponent's repair and resupply processes cause a component to be awaiting parts (AWP), this effectively creates an additional pipeline segment in which the component waits until all of its subcomponents can become available. Thus, the number of components AWP for a given subcomponent at each base (or CIRF) combines with the number of components in repair and on order to increase the total pipeline quantity. As described later, the total pipeline quantity at a base affects aircraft availability.

When a component consists of more than one subcomponent, the repair facility may choose to cannibalize serviceable subcomponents so that nonserviceable subcomponents are consolidated on the fewest possible components. Cannibalization would minimize the number of AWP components, without affecting the demand or component support processes. In Dyna-METRIC, one may specify whether subcomponents will be cannibalized or not at each base or CIRF.[6]

The Pipeline Probability Distributions: How Random Failure and Repair Processes are Represented in the Model

Failure and repair processes are typically not deterministic, so the actual number of items in a pipeline may differ widely from the expected value. Hillestad and Carrillo (1980) demonstrated that the

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[6] Generally, subcomponents are easily cannibalizeable in a repair shop. But some shops may be prohibited from cannibalizing components to avoid the wear and tear introduced by that process or to avoid transferring subcomponents with low remaining expected lifetimes to newer components.

number of items in repair would assume a Poisson probability distribution, given certain assumptions about the failure and repair processes. To compute that distribution, we need only its mean, or expected value. Thus, the model uses the total pipeline quantity for each component to compute the cumulative probability distribution, i.e., an array of probabilities that fewer than *n* components are in all pipelines.

The result makes some strong assumptions about the failure and repair processes: It assumes that failures are not correlated and that the repair process does not change as a function of failures. If failures should arrive in clusters or if the repair process accelerated or decelerated dramatically as failures occurred, the assumptions would be violated and the pipeline probability distribution would not be Poisson.

If any real-world failure and repair processes were analyzed in fine detail, the assumptions would probably be violated. Most repair shops provide priority support to a component whose failure rate has increased substantially, thereby effectively reducing its repair-cycle time (RCT). Moreover, failures are often correlated, because a failure may trigger increased vigilance or even special inspections to detect emerging problems.

Fortunately, the Poisson distribution is quite robust; a substantial deviation from the assumptions is required to make the resultant distribution vary strongly from the assumed Poisson distribution. Thus, it has been accepted widely in numerous stockage computations models, including METRIC (Sherbrooke, 1968), and (implicitiy) in the WRSK/BLSS computations (AFLCR 57-18, 1979).

Further, it is a unique characteristic of the Poisson distribution that the sum of several other (discrete) distributions converges toward it. Thus, even if one pipeline segment's process did violate the assumptions, the total pipeline would still tend toward a Poisson distribution. In Dyna-METRIC, we are most concerned with the total pipeline distribution, because it directly affects aircraft availability. Thus, the summation of the several pipeline segments in Dyna-METRIC should dampen out any non-Poisson effects related to a single pipeline segment.

Alternate Pipeline Probability Distributions

Some demand and repair processes violate the assumptions needed to use the Poisson distribution; that is, some tend to "cluster" failures into groups, and others tend to "space" failures into more periodic patterns. For example, some components degrade if they sit on the shelf too long. A failure of one of these components on an aircraft may trigger a string of related failures as the shelf stock is installed for the first time and found unusable. Alternately, some components, such as tires, are regularly replaced on a schedule. Once a tire has been replaced, it is unlikely to need replacement until the next scheduled change.

To accommodate those processes, Dyna-METRIC incorporates two non-Poisson probability distributions. The negative binomial distribution simulates clustering and the binomial distribution simulates spacing.

To select the distribution appropriate to a particular component support process, the user must supply an additional parameter: the distribution's variance-to-mean ratio. For the Poisson distribution, that ratio is always 1.00; for the negative binomial distribution, it must exceed 1.00; for the binomial, it must be less than 1.00.

It is rarely possible to obtain the data needed to establish that a component's pipeline has a non-Poisson distribution Therefore, analyses generally assume that the Poisson distribution adequately approximates the distribution for most components by setting all variance-to-mean ratios to 1.00.

How Components Affect Available Aircraft

Just as subcomponents' support processes affect AWP components, component support processes affect the number of available aircraft at each base. When the total pipeline quantity at a base exceeds that location's available stock, aircraft may become degraded from their nominal FMC status as the failed items are removed. To estimate that effect probabilistically, the model computes the pipeline probability distribution explicitly (i.e., the probability that *n* or fewer components are in the pipeline), then it shifts that distribution by the base stock level. This creates a backorder distribution (the probability that n or fewer components have been removed *but not yet replaced* in the base's aircraft).

In the model, these "holes" in aircraft represent backorders for components *as seen at the flight line.* This definition differs from the usual resupply system definition of backorders, i.e., unfulfilled requisitions from other supply echelons. Typically, that narrower definition of backorders is used to monitor and control the resupply system efficiency, because it reflects some unexpected delay in resupply processes or some maladjusted stock level.

But it is an unreliable, "noisy" indicator for forecasting how aircraft capability would be affected by the logistics system. In the narrow definition, significant numbers of aircraft could be degraded for components that were in local repair but have no backorders. Alternatively, there could be numerous unfulfilled requisitions without any aircraft holes for the components.

The narrow definition also erroneously implies that the only solution for forecasted backorders is more stock or better resupply support. In fact, the local repair process could be modified to increase its productivity (e.g., repair time could be reduced through procedural changes or additional resources) or increase its share of total repair production (e.g., through procedural changes or enhanced technology for the local repair shops). Thus the narrow definition inappropriately constrains the range of alternatives that might be considered to reduce aircraft holes.

The broader meaning of backorders was chosen for Dyna-METRIC because it relates aircraft availability to the functioning of the logistics support system as a whole. Using this broader definition, the model forecasts how the logistics system would affect ultimate wartime capability, and it expressly encourages tradeoffs between repair and resupply alternatives.

Just as subcomponent cannibalization can increase the number of components available, component cannibalization (i.e., across aircraft) can increase the number of aircraft available. Dyna-METRIC computes available aircraft with full cannibalization and with no cannibalization.

How Degraded Aircraft Limit Expected FMC Sorties

The model assumes that each FMC aircraft at a base is available for wartime sorties and can fly at the maximum sortie rate[7] for the entire day. If there is some probability that an aircraft is NFMC, the model estimates its sortie contribution by multiplying the minimum sortie rate by the probability the aircraft is FMC. Sorties across all aircraft at the base are summed up to the requested sortie rate or the number of FMC aircraft, whichever comes first.

COMPUTING REQUIREMENTS FOR PROBLEM ITEMS, INCREASED STOCK, OR ADDITIONAL TEST EQUIPMENT

To compute resource requirements, it is necessary to specify a wartime capability goal and a general strategy for attaining that goal. To specify the wartime capability goal, the model accepts the minimum fraction of the theaterwide aircraft fleet allowed to be NFMC with a given confidence level. Dyna-METRIC accepts three strategies: external operator intervention, buying spare parts, and buying additional test equipment.

Identifying Problem Parts

In the first strategy, the user and the model interact to redesign the logistics support system in detail. Dyna-METRIC identifies support constraints, and the user adjusts the support system parameters to eliminate or overcome those constraints. In its problem detection and diagnosis role, Dyna-METRIC identifies the minimum number of "problem" line-replaceable units (LRUs) whose support must be improved to achieve the target aircraft availability. Essentially, the model finds the "worst part" (the one most likely to exceed the target NFMC level) at the base with the highest percentage of NFMC aircraft at the time of analysis, pretends that LRU will *never* cause more than the target

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[7] The daily sortie rate for an FMC aircraft depends on the aircraft employment plan, the flight-line resources available, and the number of FMC aircraft. Thus, all those factors must be considered if expected sorties are used to evaluate capability. The model requires external analyses to determine a maximum daily sortie rate.

percentage of NFMC aircraft *anywhere*, and then searches for the next worst part until all bases achieve the NFMC target. Thus, the model provides a minimum ranked list of components whose support the user must improve if the NFMC target is to be achieved.

Interestingly, this strategy does not foreclose any "get-well" options for the user. Support for the problem parts may be improved by any combination of improved repair times, increased reliabilities, redistributed repair, enhanced transportation and distribution, or reallocated stock levels. Using this strategy, users may look beyond the traditional response of simply buying more stock.

But some alternatives may not be effective for some components. For example, reducing base repair times may have little effect on components that typically cannot be repaired at base level. To help users identify effective component get-well plans, Dyna-METRIC supplements the ranked problem LRU list with diagnostic information about how many of each LRU are distributed in various pipeline segments. Those relative quantities indicate which pipeline segment most affects support to that component. Thus, a component that is seldom repaired at base level would have a larger quantity on order than in base repair. Obviously, reductions in base repair time for that component would be less effective than reductions in off-base transportation or resupply times.

Computing Stock Levels

The second strategy ignores get-well solutions other than additional component stock. It suggests components (and subcomponents) to buy to approach the NFMC target percentage at minimal stockage cost. Two substrategies may be employed: buying spares to assure that each component will achieve the target NFMC goal (disregarding other components)*, or buying spares to assure that *all* components jointly achieve the NFMC goal. Obviously, the latter goal is more demanding, because it recognizes the interaction between the components' probability distributions to affect NFMC aircraft.

* This substrategy *does not* fully achieve the overall NFMC goal, because the components' probability distributions interact. If two components each had 0.1 probability of causing too many NFMC aircraft, they would jointly have a 0.19 probability of causing too many.

If the objective is only to assure that each component does not violate the NFMC goal with the stated confidence level, the model uses the components' individual total pipeline probability distribution and increases the stock until the stated confidence level is achieved. If the objective is to assure that all components jointly achieve the NFMC goal, the model first makes sure that each component achieves the goal individually (as above), then it "buys" a few more components across the full range of components to achieve the overall goal. The strategy proceeds one step at a time at each base (or CIRF), "buying" the component that most increases the location's probability of achieving the NFMC target (at the least cost) until the target is met.

The stockage algorithms in Dyna-METRIC assume that any initial stock levels entered by the user represent a sunk cost that cannot be recovered. Thus, existing stock is retained throughout the analysis and only marginal stock additions are made to improve performance. Of course, the stockage algorithms could be run with zero input stock, but the actual stock mix (and costs) would be different.

If more than one time of analysis is used when computing stock, the stock is purchased for each time of analysis in the sequence entered by the user. Thus, one could "buy" stock for day 10 and then day 30, or vice-versa. In dynamic scenarios, this may lead to slightly different stockage mixes with different total marginal costs, because each component will have different pipeline quantities at different times.

Just as component stock requirements can be computed, so can subcomponent stock requirements. The only difference is that the model seeks to buy enough subcomponents to assure that each component will achieve an AWP goal, assuming full cannibalization of subcomponents across components. Technically, this measure is known as a "ready rate." The model buys enough subcomponents (either individually or across the component) to assure that fewer than a given number of components will be AWP, with a user-specified confidence level. The AWP goal used for each subcomponent is stated in aircraft set equivalents, so that more subcomponent backorders are allowed if the component or subcomponent quantity per application (QPA)--the number of units installed on the next higher assembly--is higher.

Computing Needed Additional Test Equipment

In the third and final strategy, Dyna-METRIC computes how many test stands would be needed to meet the total expected repair demands for all components served by such test stands by the time of analysis. Basically, the model computes how much test time would be needed if all failed components were to be repaired by the time of analysis, then it buys additional test stands to cover any shortfall in test time.

When the model adds additional test stands for a deploying unit that arrives at a bare base, it assumes that the additional stands will be deployed with the first increment of test stands. Thus, if the first test stands do not arrive until late in the scenario, more test stands will be required to overcome the accumulated repairs in the time remaining.

Often, additional test stands may not be a cost-effective alternative for coping with early surges in component demands. Because a very large number of test stands would be needed to clear all component queues by the end of a surge, the stands would be under-utilized at other times. Thus, a mixed strategy of buying test stands for sustained operations and stocks to cover transient surges is often more cost-effective.

MODEL LIMITATIONS--WHAT DYNA-METRIC DOES NOT DO

No model ever mimics the real world exactly. Most models can represent accurately only a few of the more important features of the system being studied. Thus, no description of a model's capabilities can be complete without a description of its limitations. Such a description allows users to determine situations in which the model can be used confidently, and those in which the model's results should be checked against other authoritative sources.

Dyna-METRIC's capability limitations are listed below:

1. Repair procedures and productivity are unconstrained and stationary (except for the test-stand simulation).

2. FMC sortie rates do not directly reflect flight-line resources and the daily employment plan.
3. Component failure rates vary only with user-requested flying intensity.
4. Aircraft at each base are assumed to be nearly interchangeable.
5. Repair decisions and actions occur when testing is complete.
6. Component failure rates are not adjusted to reflect previous FMC sorties accomplished.
7. All echelons' component repair processes are identical.

Some capabilities were excluded from the model because they fell outside the realm of component repair. More often, capabilities were excluded because no one has yet solved the relevant problems mathematically. Continuing research is being done on at least two of those problems (constrained repair and sortie-dependent failure rates).

We have developed workarounds for many model limitations. Where a workaround is well known and tested, it is described after the limitation itself.

Unconstrained and Stationary Repair Procedures and Productivity

In the real world, total repair cycle time (RCT)--the time from a component's removal from the aircraft until its return to supply--depends on the availability of repair and spare-parts resources. When more components are queued up for repair, the average total repair time (including queuing and "hands-on" repair times) for all components increases. As more repair capability (personnel, equipment, facilities, procedures, and training) becomes available, queuing time and backlog decrease.

A Dyna-METRIC user may choose not to specify the test equipment and its constraints for some or all components. In those analyses, the model treats each component independently, assuming that "ample" repair resources exist to achieve the user-specified RCT. In those cases, the model interprets the test time as total RCT, which includes delays for limited repair resources. Because the model has no information about how additional repair resources for those components might improve repair time, it implicitly assumes that ample repair resources exist to assure that the RCT remains relatively constant.

That assumption is probably invalid in those scenarios where wartime demands and support resources or procedures fluctuate dramatically, but it is often required when little or no information is available regarding the detailed repair process.

When appropriate data exist, the user can specify test-equipment productivity constraints that Dyna-METRIC will use to estimate how queuing for repair resources (e.g., test teams, mockups, or ATE) would affect wartime capability. But those data may be difficult or costly to obtain. Special data collections may be warranted for important problems, but users may not have the resources or time to gather such data for more mundane problems. In those cases, the model may underestimate the degradation of wartime capability due to demand surges or temporary disruptions of repair and resupply.

Even when sufficient data exist to model constrained repair, the model provides only a first approximation to the effects of dynamic changes in failure rates, test equipment availability, and priority repair. Crawford (1982) describes a precise theoretical model for test equipment constraints that has considerably greater accuracy but that requires greatly increased computer resources to solve.

FMC Sortie Rates Independent of Flight-Line Resources or Operational Plans

Dyna-METRIC assumes that the average FMC aircraft can complete a given number of sorties per day. In the real world, flight-line resources such as flight-line maintenance crews, fuel trucks, and munitions loaders limit a base's ability to turn (recover, replace failed components, reload, and relaunch) aircraft. Moreover, operational plans may call for using the available aircraft in ways that preclude efficient use of those flight-line resources (by massing aircraft sorties, for example). Thus, the flight-line resource availability and the operation plans may affect the number of aircraft sorties in a more complex manner than the essentially linear relationship modeled in Dyna-METRIC. To the extent that maximum sortie rates are affected by flight-line resources and operational plans, the model's expected daily sorties forecast may be in error.

As a workaround, one can use an external model of the flight line to determine the appropriate maximum sortie rate for the flight-line resource constraints and employment plan of interest. Indeed, Clarke (1983) used the Logistics Composite Model (LCOM) of base operations and Dyna-METRIC interactively to study tradeoffs in enhanced base support. Dyna-METRIC was used to estimate the number of aircraft available for flying, and LCOM was used to estimate the maximum sortie rate that could be achieved with those aircraft.

Variation of Component Demand Rates Only with Flying Intensity

The model assumes that component (and subcomponent) failure rates depend solely on flying hours at each base. Thus, components fail more frequently when aircraft flying time is high than when it is low (in the model). But some components' failure mechanisms may depend less on flying hours than on other factors. For example, tire consumption probably depends more on the number of landings than on the number of flying hours. Similarly, gun-barrel consumption probably depends on the number of rounds fired, not the number of flying hours.

Most of those special items' failure rates can be converted to flying-hour equivalents for any given scenario. Thus tire consumption per sortie can be converted into an equivalent flying-hour failure rate, given the average sortie length expected in the scenario. In a similar manner, the average failure rate for gun barrels can be derived from the number of rounds expected to be fired on an average sortie and the sortie length. For the vast majority of components, there is a flying-hour failure rate that approximates the actual demand mechanism.

However, the demand mechanism may change during a scenario. In that case, it is necessary to change some components' basic failure rate per flying hour in a Dyna-METRIC analysis of the scenario. For example, some components are required only for certain missions. Unless the subsystems containing those components are fully exercised on each mission or during the post-flight inspections, real-world component failures may not be discovered until those particular missions are executed. These delayed discoveries might cause a "surge" of failures in some real-world scenarios where there are dramatic mission changes over time (e.g., from air-to-air missions to air-to-ground missions).

Alternatively, one might wish to use the model in a "time compression" mode to study peacetime support that changes slowly over time. Over suitably long periods of time, component failure rates change as engineering modifications are introduced to improve reliability. Changes in peacetime deployment, assigned mission, or engagement tactics may also cause some changes in forecast flying-hour failure rates.

To the extent that wartime causes a dramatic change in mission requirements at the beginning of a scenario, one may use the "nonlinearity" parameter to adjust the failure rates for the transition from peacetime operations to wartime. But subsequent changes can not be introduced during a single run.

We chose not to incorporate a capability for handling time-dependent failure rates in the model in order to keep the input formats relatively simple. Had failure rates, repair times, and other component data been allowed to vary over time, the quantity of data that might be entered (and saved internally) would have increased enormously.

A user can work around this limitation by bootstrapping two runs together. First, the model is run with the failure rates for some initial time period before the expected change in failure rates. At the conclusion of that run, the forecast pipeline quantities can be saved in a file that the pipeline initialization program can read. Then a second run can be made with different failure rates for the subsequent period.

Interchangeability of Aircraft at Each Base

The model's computation of NFMC aircraft assumes that all aircraft at a base are composed of essentially the same components. Thus, it assumes that the aircraft, their sorties, and their components are interchangeable.

But a real base's aircraft may include components that are not interchangeable. If some fraction of aircraft at the base have one set of unique components *added* to the basic aircraft (i.e., in addition to components on all other aircraft at the base), the percentage of that base's aircraft with those components may be indicated to the model. The model will then attenuate demands for that subset of components, based on the percentage of base aircraft that contain that subset. Further, the model will cannibalize the "unique" aircraft for other parts if those aircraft are already NFMC because of a unique part, and it will cannibalize any nonunique aircraft for parts needed to make the unique aircraft FMC. As long as only one colocated aircraft type has unique components, the model's NFMC aircraft computation is correct.

But the model's NFMC computation is incorrect if more than two colocated aircraft types (say, Type A and Type B) have unique stock. Essentially, the model would think it could cannibalize one Type A aircraft component from one of the Type B aircraft. If parts cannot be interchanged, the model might erroneously cannibalize some backorders for the wrong aircraft. Generally, that would lead to an overestimation of wartime capability.

A workaround for this limitation would split the single base into several "bases"--one for each unique aircraft type. Then, all base repair and stock would be placed in a CIRF, where they could serve those "bases" equally (with 100 percent NRTS and zero transportation lags). Thus the different aircraft types would share common facilities and resources (just like the real aircraft), and the model would not erroneously cannibalize components across different aircraft types.

Occurrence of Repair Decisions and Actions After Testing Is Complete

Dyna-METRIC uses a single number to represent the entire repair process: the average repair time. But real component repair processes are as richly varied as the components themselves. If procedural variations exist that affect component support without affecting total repair time, the model may inaccurately represent their effect.

One important procedural variation is the dominance of either diagnostic activity or physical repair activity over the repair process. In Dyna-METRIC, the repair process is assumed to be dominated by a long diagnostic period, followed by rapid physical repair. In cases of component support processes where the diagnosis period is short but the physical repair is long, the model may overestimate the number of AWP components, because subcomponent failures discovered early in the component repair process may be repaired simultaneously.

If a component's repair process is known to deviate from that assumed by Dyna-METRIC,[9] the component and its subcomponents (i.e., LRUs and SRUs) can be treated as independent components (LRUs). This approximation capitalizes on the fact that the discovery of a failed subcomponent on a larger component occurs at almost the same time that the failed component is discovered. By treating the component and its subcomponents as separate components, one can initiate the repairs simultaneously. Of course, it is necessary to account for the subcomponent stock actually on components, so one must increase the subcomponents' stock levels, based on the number of components available.

Lack of Adjustment of Component Failure Rates to Reflect Previous Failures

The model does not use its prediction of expected FMC sorties to drive current or future component failures. Rather, it assumes that some PMC aircraft will be used to fly sorties if FMC aircraft are not available. Thus, the model uses the user-entered sortie rates (rather than the computed FMC sorties) to compute component failures and pipeline quantities.

In some scenarios with very high sortie rates or inadequate support, the aircraft fleet may become so degraded that very few PMC aircraft will exist to meet the demanded sortie rate. In these cases, the model will overestimate demands, after some initial period, and will therefore underestimate sorties and wartime capability.

When this situation is encountered, the user can execute the model iteratively, manually feeding back the expected FMC sorties computed by Dyna-METRIC as sorties demanded by the user. Feeding back the FMC sorties seldom has a noticeable effect on NFMC aircraft unless more than half of a base's aircraft are NFMC.

---

[9] The analyst may not know every component's repair process, especially when the joint effects of several hundred components are being modeled. When the repair processes are not known in detail, conservative analysts may prefer to use the process portrayed by Dyna-METRIC to estimate the lower bound on performance.

Identical Component Repair Processes at All Echelons

The model was originally designed to investigate logistics issues within a theater. The second echelon of repair and supply was intended to be applied where some fraction of base-level repair was centralized off-base, as in the PACAF Centralized Intermediate Logistics System (CILS). For that reason, the repair processes at the base and the second echelon are identical except for the fraction of components that are NRTS at each level. Specifically, the repair times are the same and the subcomponent demand rates are the same.

Repair processes at a depot differ considerably from those at a base. The central repair facility has different technologies that enable it to repair component failures that a base or a CIRF cannot handle. The different processes typically have different time requirements, and they often produce a different mix of subcomponent demands. Thus, the model cannot directly use the CIRF repair process to approximate the effects of a depot on wartime capability.

A limited workaround is available for depot repair times. Because depot repair times are typically *much* longer than base repair times, one can use the CIRF's administrative delay[10] to prolong the time *all* components spend in the depot. Future versions of Dyna-METRIC will permit more accurate specification of the depot-level repair processes.

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[10] The administrative delay at a base or a CIRF is intended to estimate the effects of undocumented handling processes associated with receiving reparables or sending serviceables. Because of the lack of data, this factor is typically not used in most analyses.

IV. USING DYNA-METRIC: A SIMPLE EXAMPLE

Like any computer model, Dyna-METRIC may initially appear complex to new users. To help overcome that initial shock, this section describes the use of the model to analyze a relatively simple problem.

First, the problem is described in general terms, then a Dyna-METRIC problem description deck is constructed. After a detailed analysis of the first set of model reports, several alternatives that might improve performance are explored to show how the model can be used in extended analyses.

THE PROBLEM: DEPLOYING A LONE SQUADRON

The problem for this example is limited to a single aircraft squadron deploying to a single base. We have also assumed that the aircraft are extremely simple--composed of only ten major components that have no subcomponents. This problem does not stress the model's ultimate limits, but it does illustrate most of Dyna-METRIC's major functions.

In our hypothetical wartime scenario, the squadron consists of 24 aircraft that deploy to a bare base. Upon arriving, the unit plans to fly three sorties per aircraft per day for the first seven days and one sortie per aircraft per day thereafter. Adequate filler aircraft exist to assure that the unit will be maintained at full strength throughout the first 30 days of the deployment.

The unit's detailed deployment plans call for the spare parts and flight-line personnel to be deployed on the same day as the aircraft, so LRUs can be removed and replaced immediately. However, limited transportation capacity will delay the deployment of intermediate-level maintenance (ILM) to repair those removed components until five days after the aircraft are deployed. Based on previous experience, technical personnel estimate that an additional two days will be required to set up the intermediate maintenance facility before repair can start on any failed components.

Because the war plan is extremely limited (only one squadron deployed), adequate transportation resources will exist to provide parts resupply from CONUS throughout the deployment. Thus the unit will receive requisitioned spares from depot sources according to wartime standards, though recent peacetime experience has been slightly better than those standards.

The initial task is to assess the unit's ability to satisfy its wartime commitment.

INPUT DATA

The problem description data for a Dyna-METRIC analysis consist of six major "sections":[1]

1. Some administrative information
2. An operational and support scenario
3. A component description
4. A subcomponent description (optional)
5. A test-equipment description (optional)
6. Stock levels

The administrative information provides some control over the model's output reports, and the parameters are determined by the kind of analysis one wishes to perform. The deployment and employment plan describes the operations and support plans for the scenario, drawn from the appropriate planning documents. The component and subcomponent descriptions, taken from engineering estimates, standard component-support management systems, or special data collection studies, describe how each part's failure and repair processes operate. The test-equipment description indicates which components' repair requires which test equipment and the test stands' quantities, failure rates, repair characteristics, and availabilities. Finally, the stock levels can be obtained from automated stock management systems or from supply plans.

[1] These sections are composed of several "blocks" of similar data.

Appendix A provides a complete description of the problem description data structure and format, including subcomponents and test equipment. Here, we describe only the data relevant to our example. We will describe each section of the problem description data in turn, so new users can see how the general problem description above can be converted for use by Dyna-METRIC.

Administrative Information Section

The administrative information for the baseline run (Fig. 5) controls the model's basic operation and labels the output report.

The first line of any problem description is a title which is merely copied onto the main report for the user's later convenience in distinguishing model runs. Though its contents are optional (it may even be blank), the title line must appear in the problem description data.

The second line contains two types of information: support-process assumptions and mission descriptions. Three support-process assumptions are specified for the example: the repair, transportation, and resupply processes will have random, exponentially distributed times; the base will encounter no administrative delays; and the CIRF will not encounter administrative delays. (The third parameter could be ignored in this initial run, because there is no CIRF; we will investigate a CIRF option later.)

```
LONE SQUADRON DEPLOYMENT--BASELINE CASE
 1 0.00 0.00                         rd aa ag nu ds
   1    2    4    7    8   10   20   30
OPT
      11 15
       8  5 .80
```

Fig. 5 -- Administrative information

The remaining information on the second line identifies the user-named mission types to which the aircraft may be assigned. They are especially useful when different mission capabilities are of concern at different times in the scenario. The analysis in this example will not be so detailed, but sample mission types have been included to provide some notion of how they would be used. The aircraft in the example can fly five missions: redeployment, air to air, air to ground, nuclear, and defense suppression.

The third line of administrative information directs the model to compute its reports for several specific "times of analysis." This allows the user to avoid unnecessary computations during periods when the forecast performance is not expected to vary significantly, yet enables him to obtain frequent reports during dynamic periods when wartime capability may change rapidly. In the example, both the flying program and the support capability change dramatically near the seventh day, so the base's performance on both day 7 and day 8 were requested. The performance on six other days was also requested to provide enough information for a reasonably smooth curve.

The fourth line marks the beginning of the Dyna-METRIC "Options" block, which indicates which optional computations or reports the user would like. In this case, Options 11 and 8 were requested. Option 11 (in the fifth line) requests that a performance report be produced that estimates the probability that 15 percent or fewer of the 24 aircraft will be NFMC at each time of analysis. Option 8 (in the sixth line) specifies that a problem parts list be generated, listing all those parts (up to a maximum of five) that would require special management to assure that the Option 11 target (15 percent of 24 aircraft) is met with 80 percent assurance.

Operational and Support Scenario

The operational and support scenario (Fig. 6) describes how the squadron's aircraft and support resources will be deployed and employed. That plan has three sequential subsections: a description of the CIRFs and bases (CIRFs precede bases); a description of transportation between the bases and theater CIRFs (if any); and a description of the aircraft deployment and employment plan, including the aircraft available at each base, their daily sortie rate and length, attrition, assigned missions, and maximum sortie rate.

CIRFs are intermediate repair facilities (perhaps colocated with a base) that repair at least some failed components removed from some bases' aircraft. If CIRFs do not exist in the scenario (as in our example), they are simply not covered in the problem description.

The bases are described in a BASE block, each on a separate line. In the example, the squadron will deploy to a location called LOC1, and intermediate-level maintenance will be deployed after a five-day delay. Before any repairs can commence, an additional two days will be required to set up the maintenance facilities.[2] Finally, CONUS resupply will begin on day 0 of the scenario--assuring continuous resupply throughout the deployment. The transportation subsection is not specified in the example because there are no CIRFs.

The aircraft deployment and employment subsection specifies how many aircraft exist at each base over time, and how those aircraft will be employed. The plan is described in several blocks that may appear in any order in this part of the problem description. In the ACFT block

```
BASE
LOC1                   5. 2.  0.
ACFT
LOC1  0.    1 24.  99
SRTS
LOC1 0.7    1  3.    8  1.   99
FLHR
LOC1 1.5   99
TURN
 3.5  99
```

Fig. 6 -- Deployment and employment plan

[2] Actually, we could have specified a deployment time of seven days with no setup time, since the model uses only the sum of these two entries. The two entries are made for convenience in gathering input data where deployment times may vary widely but setup times may be relatively constant.

for the example, LOC1 initially has 0 aircraft, but it will receive 24 aircraft on day 1.[3] The SRTS block indicates that the aircraft will fly an average of three sorties per day until day 8, when the rate will decrease to one sortie per day. The FLHR block tells the model that the aircraft will experience average sortie durations of 1.5 flying hours throughout the scenario. The TURN block indicates that experienced operations and logistics specialists judged that these aircraft could each average a maximum of 3.5 sorties per day throughout this deployment.

The aircraft level, sortie rate, sortie length, and maximum sortie rate blocks must be specified in all model runs, because the parts failures and sortie rate computations require those data. Other (optional) blocks may specify each base's time-dependent assigned missions (the MESL block) and air attrition rates (the ATTR block) expected for each base's aircraft. If those blocks are not specified, the model assumes that all missions are required daily, and that there is no attrition.

Component Description Section

The component description section (Fig. 7) describes the nominal failure and repair characteristics of the major components (LRUs). Because of the limited space on a single input line, that information is specified in two blocks: a basic LRU description block, and an optional APPL block (which specifies the application fraction of the components on the aircraft).

The basic LRU block describes the failure and repair characteristics of each component. Thus, the first component in the example is named 1430000435192BF, and it has a failure rate of 0.00039 failures per flying hour, a 0.07 chance of being declared NRTS at a base with its own ILM, a certainty (probability of 1.00) of NRTS at a base supported by a CIRF, a 0.07 chance of NRTS at a CIRF, an average repair

[3] That level of aircraft will be maintained until well after the last time of analysis (day 30). The model requires that a time after that date be entered on the operational scenario to signal that no more changes will occur. Therefore, we have entered 99 to signal that the 24 aircraft will be available until the end of the scenario.

```
LRU
1430000435192BF  .00039 .07 1.00  .07   2.0   4772. 1 1 1 1.0 1.0 23 20
1430000780463BF  .00404 .06 1.00  .00   2.0  31119. 1 1 1 1.0 1.0 23 17
1430001114411BF  .00036 .21 1.00  .21   3.0   4800. 1 1 1 1.0 1.0 23 20
1430001117990BF  .00151 .59 1.00  .59   3.0   7635. 1 1 1 1.0 1.0 23 17
1430001458910BF  .00449 .04 0.92  .00   2.0   8699. 1 1 1 1.0 1.0 23 20
1430001830955BF  .00607 .04 0.87  .00   2.0  12418. 1 1 1 1.0 1.0 23 17
1430001834016BF  .00057 .24 1.00  .24   3.0   3747. 1 1 1 1.0 1.0 23 17
1430001834082BF  .00448 .09 1.00  .09   2.0  20828. 1 1 1 1.0 1.0 23 17
1430001946460BF  .01700 .06  .80  .06   2.0  23960. 1 1 1 1.0 1.0 23 17
1430002356325BF  .01092 .28 1.00  .33   2.0  36653. 1 1 1 1.0 1.0 23 17
APPL
1430000435192BF  01000 1.0          74bt0
1430000780463BF  01000 1.0          74bh0
1430001114411BF  01000 1.0          74bk0
1430001117990BF  01000 1.0          74bl0
1430001458910BF  01000 1.0          74fa0
1430001830955BF  01000 1.0          74bc0
1430001834016BF  01000 1.0          74be0
1430001834082BF  01000 1.0          74ba0
1430001946460BF  01000 1.0          74bp0
1430002356325BF  01000 1.0          74bd0
```

Fig. 7 -- Component description

time of 2.0 days, and a cost of $4,772. Further, each aircraft contains only one of these components, the component can be repaired locally (once ILM is available), it would be repaired by a CIRF if one were available, its wartime failure rate per sortie is directly proportional to peacetime experience, it has a Poisson distribution (i.e., the variance-to-mean ratio is 1.00), and it has a standard CONUS order and ship time of 23 days in wartime (although recent peacetime experience was slightly better at 20 days).

In the optional APPL block, the fraction of each base's aircraft fleet that uses each component and each component's mission essentiality are specified. If this block is omitted, the model assumes that all bases' aircraft contain all components and that all components are required for all missions. Similarly, if a component is omitted from the block, the model assumes that all bases' aircraft contain the component and that the component is required for all missions. In this example, all of the components appear on every aircraft, but they are required only for the air-to-air mission.

Subcomponent Description Section

Subcomponents were excluded from this example, but their input data requirements are similar to those of components, except that the input format differs. In addition, the subcomponent's indenture relationships (i.e., which subcomponents physically mount on each component) must be specified. As with previous input data that were not needed, the SRU and INDT blocks that describe the subcomponent support characteristics and indenture relationships can be omitted from the problem description for this example.

Test-Equipment Description Section

Test-equipment constraints were not specified in the general problem description, so they do not appear in the example. A later excursion will introduce test-equipment constraints, and those data will be described in that context.

Stock Level Section

The stock level section (Fig. 8) sets the initial stock levels for each component at each CIRF and base. The stock levels at all CIRFs and bases are indicated on a single input line for each component. On each line, the CIRFs' stock levels appear before the bases'. Within each group (CIRFs or bases), the levels appear in the order in which the

```
STK
1430000435192BF    1
1430000780463BF    3
1430001114411BF    1
1430001117990BF    2
1430001458910BF    5
1430001830955BF    4
1430001834016BF    1
1430001834082BF    2
1430001946460BF   10
1430002356325BF    2
END
```

Fig. 8 -- Component stock

sites were first entered (i.e., first CIRF first, second CIRF next, etc.).

In the example, stock levels have been set to represent the stock (for each component previously entered in the model) that the deploying unit plans to take with it.

OUTPUT REPORTS

The output from Dyna-METRIC is divided into two files, each of which is composed of several reports. The main output file (the primary output) summarizes the results of the model's operation and (optionally) echoes the user's inputs (the problem description). The (optional) secondary file describes the model's detailed forecasts for each LRU, indicating the number of units in each pipeline segment and the expected backorders (aircraft holes) at each base.

The program also generates several other intermediate and output files useful only to itself. They are not described here but are listed in Appendix B. One of those files will be used in a subsequent excursion from the baseline example to initialize the pipelines.

Here, we describe only the primary output as it would appear in a performance run (Options 11 and 8). Other primary reports will be described as they are needed to support our example. The secondary file is useful primarily for monitoring internal model computations on very small datasets. In real problems, the secondary output is too voluminous to use and interpret, so we do not describe it here. Some data from the secondary output are selected and summarized in the problem parts report, which appears in the primary output.

The Primary Output

The model's primary output depends on the options selected by the user. It may contain a performance report, a stockage report, or both. At the user's discretion, it may also print out an echo of the problem description.

Though none will appear in this description, Dyna-METRIC error messages may also appear in the primary output. (See Appendix C for a summary of the model's stop codes and error messages.) In general, any error message will cause nearly immediate termination of the model operation. Errors in the problem description are the exception; they are noted immediately, but the remainder of the problem description will be read (and other errors noted) before the run is terminated. Thus, all simple input errors can be detected in a single run without executing the model unnecessarily.

The performance reports and the stockage reports will be described below in the context of the example analysis, so only the echo of the user inputs will be described here.

Like the original input problem description, the echo of the user inputs is organized into cohesive sections of related information. Those sections echo the administrative information used by the model, the aircraft operational scenario, the component and subcomponent characteristics, the support scenario, and the stock deployment plan.

First, the administrative information, including the analysis title, the administrative delays, the analysis times, and the options selected, is echoed back to the user (Fig. 9). (Some additional administrative information derived from the operational scenario plan, i.e., the number of bases and CIRFs in the scenario, is also reported here.)

```
DYNA-METRIC -- RELEASE 3.0.4  (AUGUST 1981)

LONE SQUADRON DEPLOYMENT EXAMPLE--AN/APQ-120 CAPABILITY

    1 BASES
    0 CIRFS
0.0   AVERAGE BASE ADMINISTRATIVE DELAY DAYS
0.0   AVERAGE CIRF ADMINISTRATIVE DELAY DAYS

ANALYSIS REQUESTED FOR TIMES      1     2     4     7     8    10    20    30

 8: LIST PROBLEM LRUS: 10 LRUS, GOAL = 0.80
11: CALCULATE PERFORMANCE AT 15% NMCS BASED ON INPUT OR PREVIOUS STOCK
```

Fig. 9 -- Administrative information echo

Next, the aircraft deployment and employment specified by the user is echoed in two types of tables (Fig. 10).

The first type of table shows the daily number of aircraft, sorties per aircraft, flying hours per sortie, and mission assignments for each base's aircraft. Each base has its own table. Only one base occurs in the example, so the report shows only the deployment and employment plan for that base. Note that the table faithfully reflects the problem's aircraft deployment and employment plan, in which the 24 aircraft arrive on day 1, fly three sorties per day for seven days, and fly one sortie per day thereafter.

The second table shows the daily theaterwide maximum sortie rate allowed per available aircraft. In our example, this was limited to 3.5 sorties per aircraft throughout the scenario.

FLYING PROGRAM FOR BASE : LOC1

DAY:	AIRCRAFT	SORTIES	FH/SRT	rd	aa	ag	nu	ds
PEACE	0	0.70	1.50					
1	24	3.00	1.50	X	X	X	X	X
2	24	3.00	1.50	X	X	X	X	X
3	24	3.00	1.50	X	X	X	X	X
4	24	3.00	1.50	X	X	X	X	X
5	24	3.00	1.50	X	X	X	X	X
6	24	3.00	1.50	X	X	X	X	X
7	24	3.00	1.50	X	X	X	X	X
8	24	1.00	1.50	X	X	X	X	X
9	24	1.00	1.50	X	X	X	X	X
10	24	1.00	1.50	X	X	X	X	X
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
30	24	1.00	1.50	X	X	X	X	X

MAXIMUM SORTIE TURN RATE BY DAY:

1	3.5
2	3.5
3	3.5
.	.
.	.
.	.
30	3.5

Fig. 10 -- Deployment and employment plan echo

The component and subcomponent data also require several tables to echo the user's inputs (Fig. 11). The first table echoes the failure and repair characteristics for both components and subcomponents. The second table echoes some characteristics unique to components and the requirements for those on the range of missions entered. The final table echoes the percentage of the aircraft at each base that contain each component.

DETAILED PARTS INFORMATION:

		LRU	TEST EQUIP.	DEM/FHR	COST($)	QPA	TEST TIME	BASE NRTS	C.B. NRTS	CIRF NRTS
LRU	1:	1430000435192BF		0.00039	4772.	1	2.000	0.070	1.000	0.070
LRU	2:	1430000780463BF		0.00404	31119.	1	2.000	0.060	1.000	0.0
LRU	3:	1430001114411BF		0.00036	4800.	1	3.000	0.210	1.000	0.210
.	.	.		.	.	.	.	.	.	.
.	.	.		.	.	.	.	.	.	.
.	.	.		.	.	.	.	.	.	.

FURTHER PARTS INFORMATION:

	LRU		LINEARITY	VAR/MEAN	OST (DAYS) PEACE	WAR	MISSIONS: rd	aa	ag	nu	ds
1:	1430000435192BF	RRR	1.00	1.00	20.0	23.0		X			
2:	1430000780463BF	RRR	1.00	1.00	17.0	23.0		X			
3:	1430001114411BF	RRR	1.00	1.00	20.0	23.0		X			
.	.	.	.	.	.	.		.			
.	.	.	.	.	.	.		.			
.	.	.	.	.	.	.		.			

APPLICATION FRACTION:

		LOC1
1:	1430000435192BF	1.00
2:	1430000780463BF	1.00
3:	1430001114411BF	1.00
.	.	.
.	.	.
.	.	.

Fig. 11 -- Portion of the component and subcomponent characteristics echo

The component support and deployment table describes how component support capabilities will vary at each CIRF and base (Fig. 12). This information is also arranged in a tabular format, with a column for each CIRF or base. As shown in Fig. 12, RRR ILM[4] will require five days to deploy (TD) and two days (TS) to set up. Further, CONUS resupply will begin at day 0 (TC), and repair times will be randomly distributed. (The remaining parameters apply to repair capability for RR parts, the time and duration of a subsequent cutoff from the CONUS, and the subcomponent (SRU) support from the CONUS. Those parameters are not used in these examples, so they will not be described here. (See Appendix A for more details.)

DETAILED INFORMATION: SET-UP PARAMETERS

	LOC1
TD	5.0
TS	2.0
TC	0.0
TDR	0.0
TSR	0.0
IC	0
TCCO	0.0
TCCOD	0.0
TDCO	0.0
TDCOD	0.0
TSRU	0.0
TPSRU	0.0
T1SRU	0.0
T2SRU	0.0

RANDOMIZED REPAIR TIMES

Fig. 12 -- Component-support deployment and employment echo

[4] RRR ILM is ILM for components coded Remove, Repair, and Replace (RRR) in the War Reserve Computations. ILM is "intermediate" repair between the flight line and depot support. RRR is distinguished from "Remove and Replace," which does not repair some components until much later in the scenario.

Finally, the program echoes the input stock levels used for performance and stockage computations (Fig. 13). (These reports appear at the end of the report, after any performance reports, because they may be modified by subsequent stockage calculations.) Again the format is tabular, with the stock level for each CIRF and base in a separate column.

```
INPUT STOCK VALID FROM TIME  0:  (ABSOLUTE)
                        LOC1
  1: 1430000435192BF     1
  2: 1430000780463BF     3
  3: 1430001114411BF     1
  4: 1430001117990BF     2
  5: 1430001458910BF     5
  6: 1430001830955BF     4
  7: 1430001834016BF     1
  8: 1430001834082BF     2
  9: 1430001946460BF    10
 10: 1430002356325BF     2
```

Fig. 13 -- Example stock level echo

ANALYZING AND INTERPRETING PERFORMANCE OUTPUTS

Dyna-METRIC provides several measures of daily aircraft wartime capability that can be used to interpret the effectiveness of component support to a force in a given scenario. In its performance reports, the model forecasts:

1. The probability that fewer than some target number of aircraft will need at least one part (assuming full cannibalization).
2. The expected number of NFMC aircraft that need at least one part to be FMC (with and without cannibalization).
3. The expected variability in NFMC aircraft.

4. The expected number of FMC sorties that could be accomplished (assuming full cannibalization).
5. The expected number of aircraft holes summed across all aircraft.

We illustrate below how one can use this information by examining the output generated by our simple example.

On day 7, the model predicts (Fig. 14) that the squadron in the baseline example can expect only a 17 percent chance of four or fewer NFMC aircraft, and it should expect about seven NFMC aircraft if they consolidate LRU holes onto the fewest possible aircraft (i.e., with full cannibalization).

Obviously, the squadron will have some difficulty achieving its target of 72 sorties on this day, even with full cannibalization. Using the user-specified sortie rate of 3.5 sorties per FMC aircraft per day, the model predicts that the unit can expect to fly only about 60 FMC sorties.

But day 7 performance represents only what can be achieved on the most stressful day of the scenario. The aircraft have been flown at a very high rate (three sorties per day) for an extended period, and there has been no component repair started (let alone completed). When performance reports for the entire scenario are combined into a graph of NFMC aircraft, the performance at other times is much better than this worst time, if a full cannibalization policy is faithfully executed

7 DAY PERFORMANCE BASED ON INPUT STOCK

BASE	TARGET NMC	PROB. 15% NMC	FULL CANN. NMC E.V.	FULL CANN. NMC S.D.	NO CANN. NMC E.V.	NO CANN. NMC S.D.	SORTIES E.V.	SORTIES S.D.	TOTAL BACK ORDERS
LOC1	4	0.17	6.98	2.63	11.03	3.41	59.38	8.87	13.44

Fig. 14 -- Portion of wartime performance report

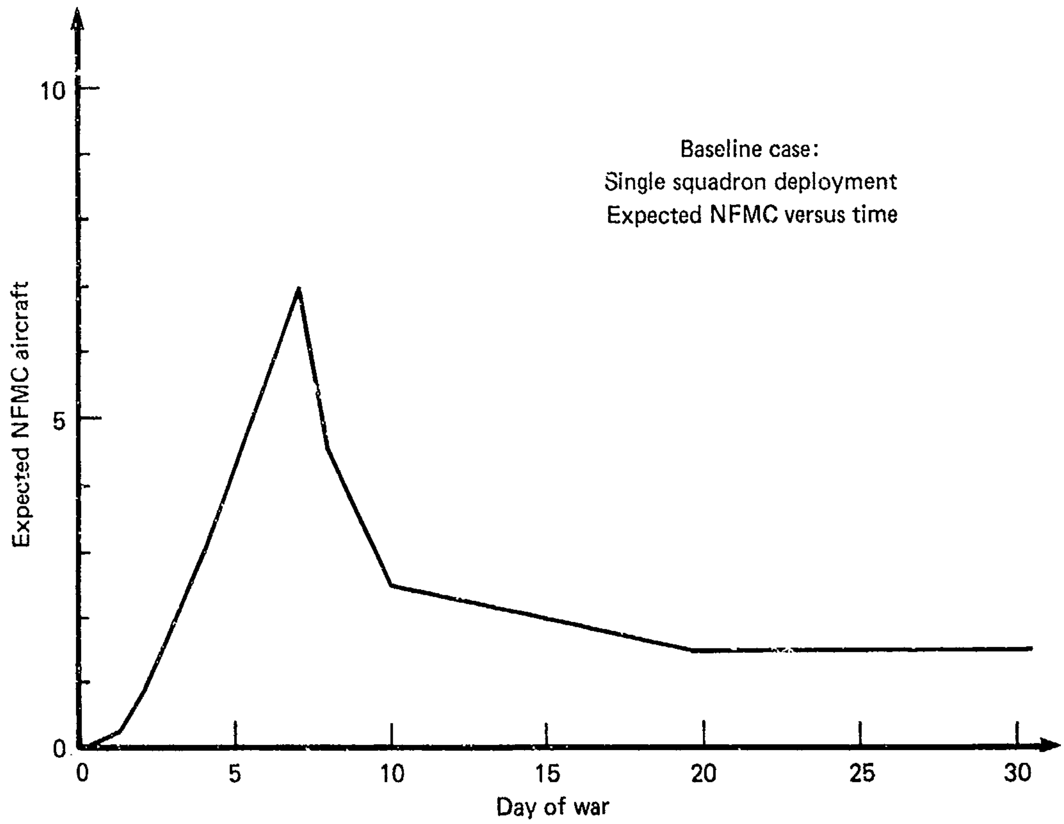

Fig. 15 -- NFMC aircraft in example

(Fig. 15). Even so, the performance reports indicate that some FMC sorties would be lost during the early part of the scenario (Fig. 16).[5]

But that performance may be overly optimistic. In the first place, the actual number of degraded aircraft in any given deployment may vary randomly from the expected number. Roughly speaking, there is a 50 percent chance that more than the expected number of aircraft will be degraded on any particular deployment. To indicate the degree of that variability, the model also reports the expected variability (standard deviation) of NFMC aircraft (Fig. 14). There is about a 15 percent chance that the actual number of NFMC aircraft will exceed the sum of the expected number and the standard deviation at any time in the

[5] Figures 15 and 16 are based on data from wartime performance reports on the eight times of analysis requested in our problem description.

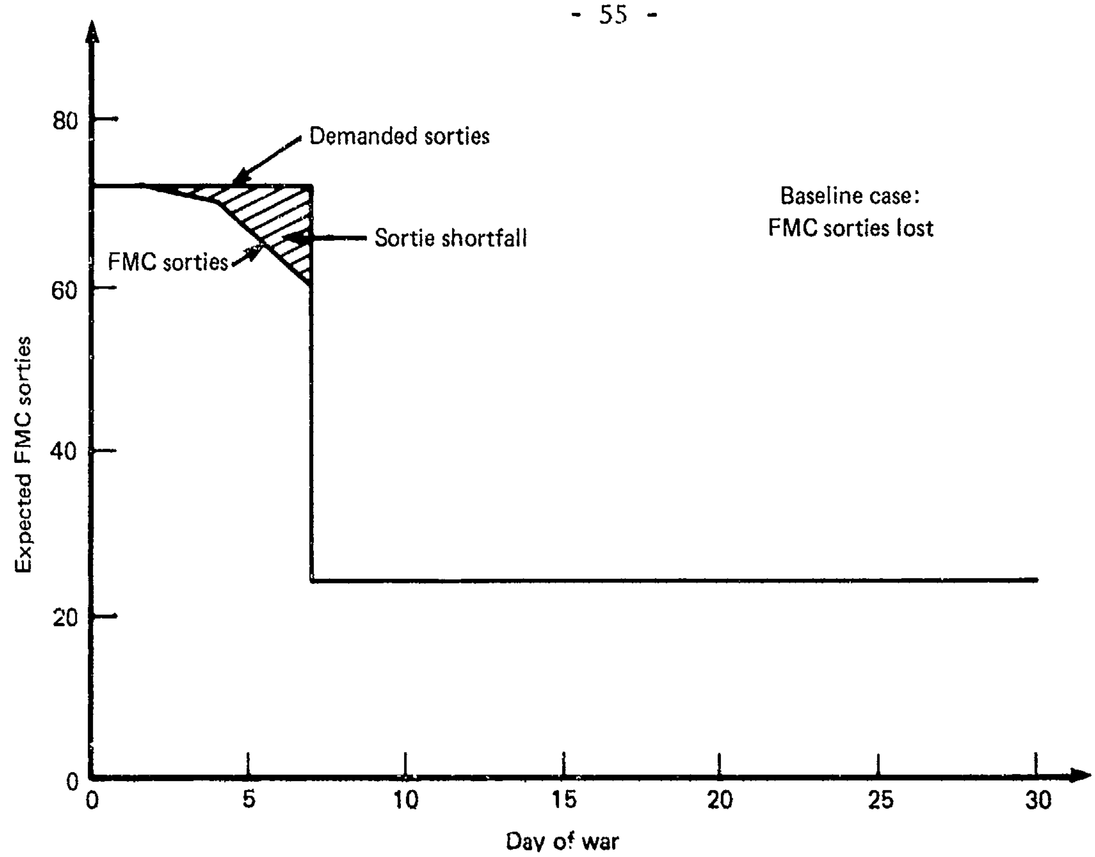

Fig. 16 -- Sorties demanded, achieved, and lost due to component support

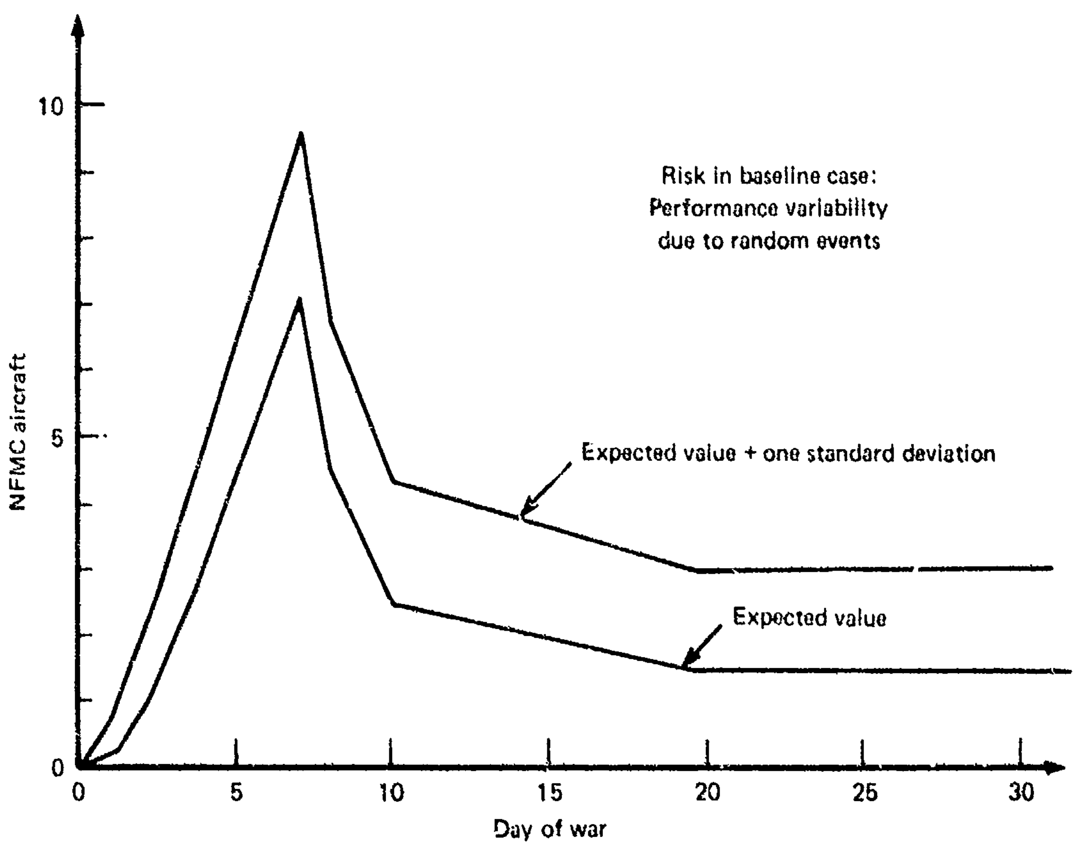

Fig. 17 -- Performance variability due to random events

scenario (Fig. 17). The degradation in performance will be worse if the deployed unit cannot exercise full cannibalization (Fig. 18).

A decisionmaker may judge that the indicated performance is not satisfactory. To find out what components and component support processes most constrain wartime capability, the analyst should refer to Dyna-METRIC's problem parts report (Fig. 19).

In the example, two of the ten major aircraft components prevent the unit from achieving the indicated goal of four or fewer degraded aircraft with 80 percent confidence. Indeed, the worst problem part (i.e., the first one listed in Fig. 19) dominates wartime capability (Fig. 20), while the second part plays only a minor role.

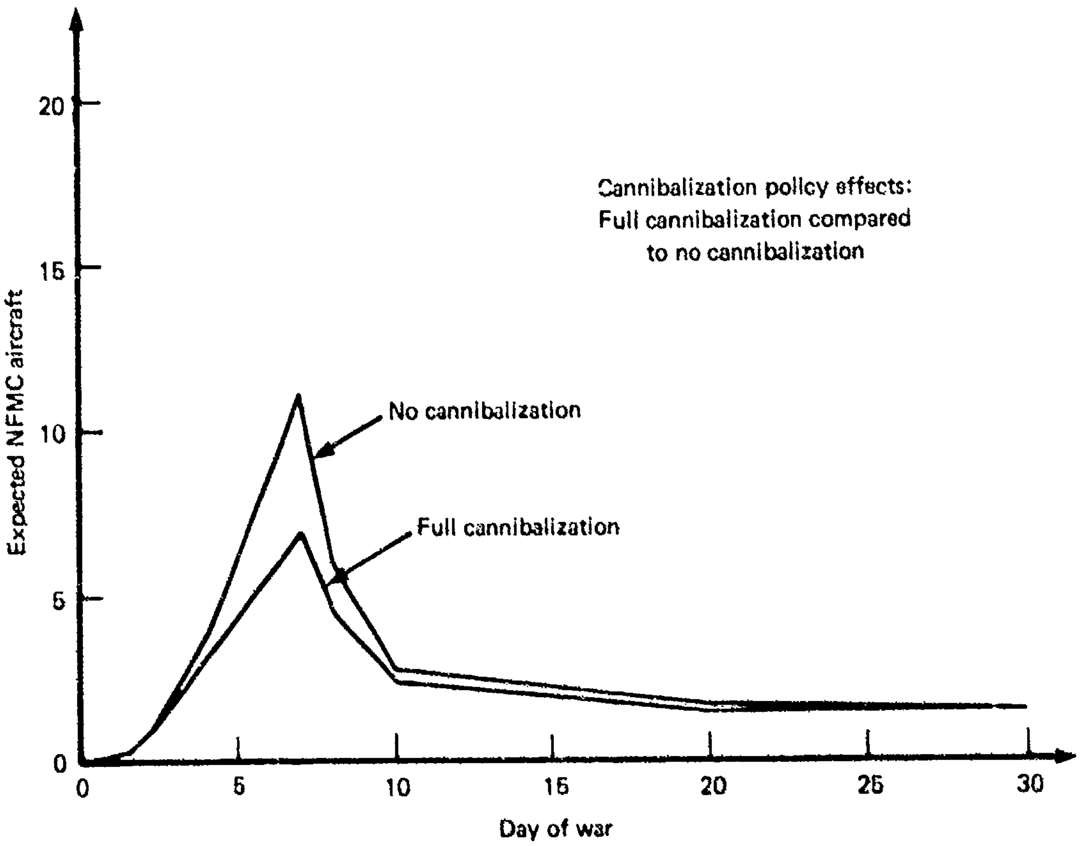

Fig. 18 -- Performance degradation with full cannibalization and no cannibalization

PROBLEM LRUS DIAGNOSIS

IMPACT: PROBABILITY OF EXCEEDING TARGET MICAP PERCENTAGE:

PROBLEM PARTS:	LOC1
1430002356325BF	0.72
1430001946460BF	0.31

ISOLATED BASE PROBLEM LRUS:

LOC1: PROBLEM LRUS:	STOCK LEVEL	SERV. STOCK	REP. ON HAND	REP. OFF BASE
1430002356325BF	2	-6.3	8.3	0.0
1430001946460BF	10	-2.9	12.9	0.0

Fig. 19 -- Problem parts report

The Dyna-METRIC problem parts report ranks components by the probability that they will cause more than the target number of aircraft down at one or more bases, and it indicates where the reparable parts are located in the system. Thus in our example (Fig. 19), the worst part has a 0.72 probability of causing an unacceptable number of NFMC aircraft on day 7. The cause of that shortfall is readily apparent when one looks at the LOC1 problem LRUs: There should be about eight reparable LRUs by day 7, but there is a stock level of only two. The problem lies in the lack of repair prior to day 7. With this imbalance between reparables and stock levels, one should expect six components removed from aircraft.

Obviously, the target performance could be achieved by simply buying more stock. Although the cost would probably be small in this simple example, the costs could be quite large for real problems, especially if the goal was to assure few degraded aircraft with high confidence.

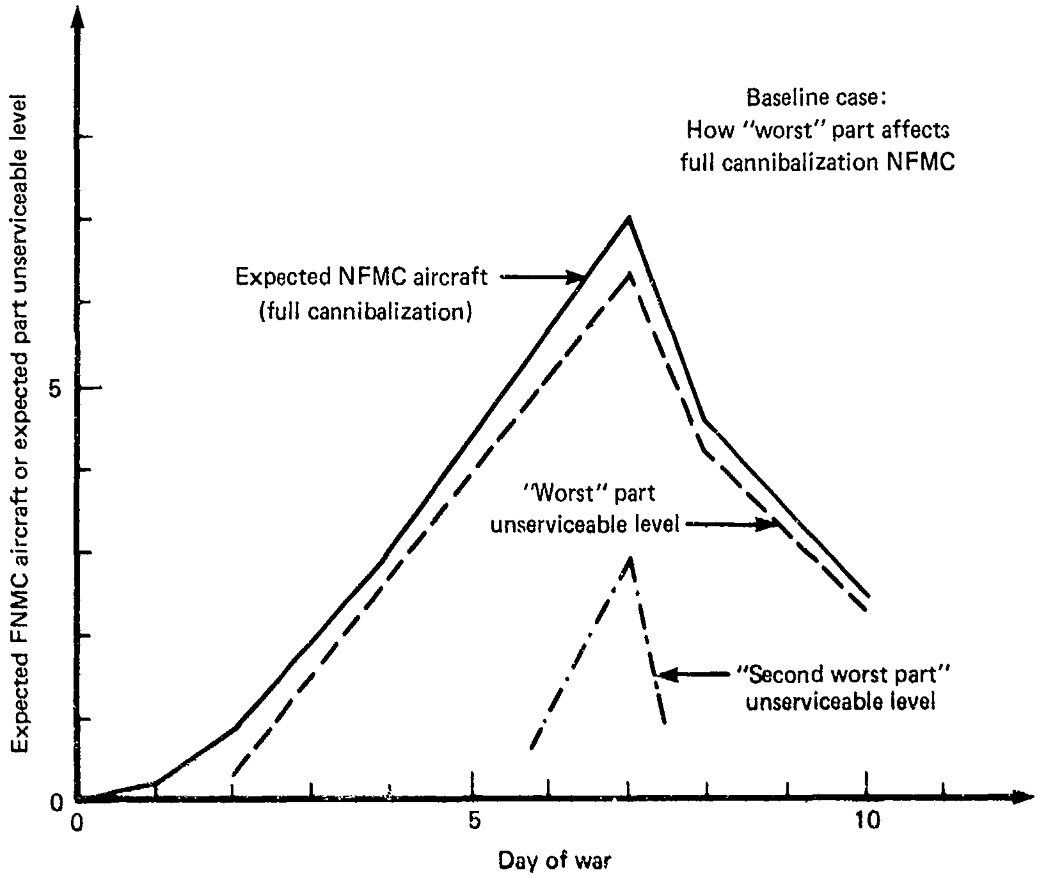

Fig. 20 -- Effects of problem parts on aircraft performance

IMPROVING PERFORMANCE: CONSTRUCTING AND EVALUATING ALTERNATIVES

Sometimes alternatives exist that do not require more stock. In some scenarios, it may be possible to redistribute existing stock (from nondeploying or late-deploying units). In other cases, it may be possible to colocate units so that the combined safety stock provides better protection. Alternatively, enhanced repair productivity may be achieved through management or increased repair resources or resupply; and transportation performance may be enhanced to remedy some anticipated temporary shortage. In the following paragraphs, Dyna-METRIC will be used to compare the effects of such proposed changes on wartime capability in our baseline example.

Reducing Repair Times to Improve Performance

Faster repair should decrease the repair pipeline size, increase average on-hand stocks, and reduce the number of NFMC aircraft. Thus, an excursion was made in which the two worst parts' repair times were halved to simulate expedited repair.

Although expedited repair does reduce NFMC aircraft late in the deployment, it has no effect whatsoever until ILM begins repairing failed components (Fig. 21). Thus, expedited repair would improve the situation once repair began, but it could not make up for the early lack of component support.

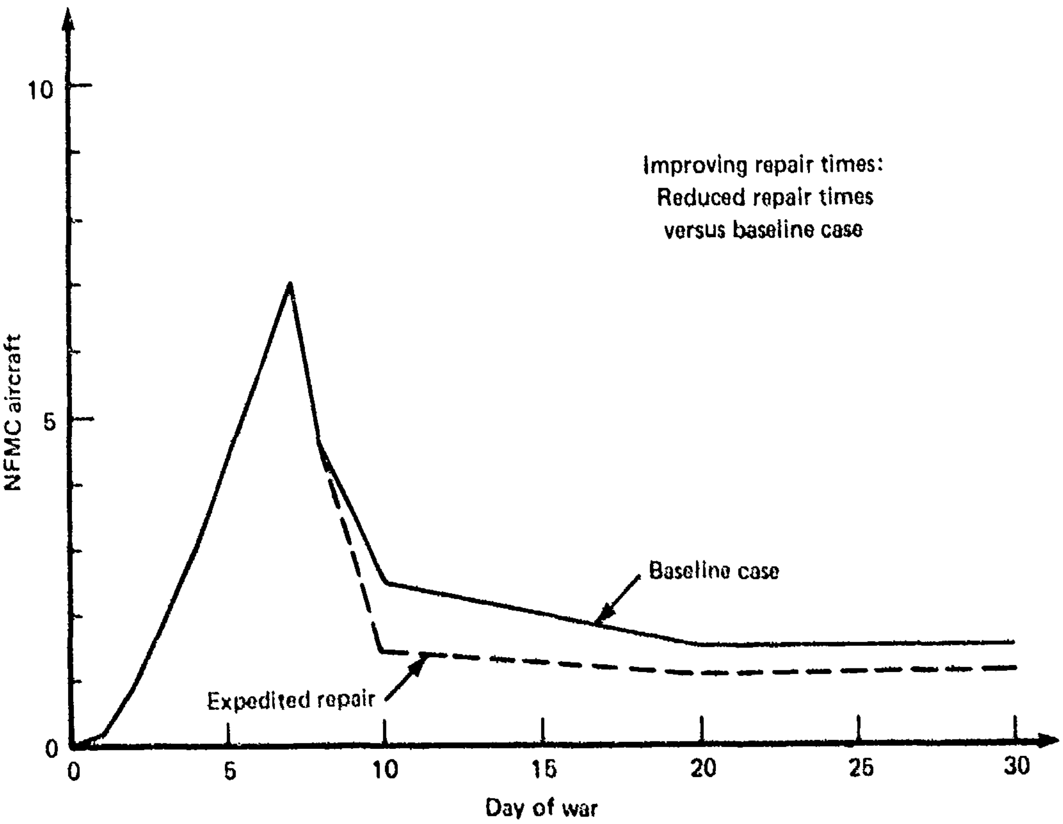

Fig. 21 -- Effects of expedited repair on available aircraft

Starting Faster--Reducing ILM Deployment Time

To overcome the lack of initial support, one must either provide earlier ILM support or additional stock support. Earlier ILM would "short-circuit" the transient support shortfall by repairing components and returning them to stock earlier. Thus an excursion was made to see how improving the ILM deployment and setup time by two days might affect wartime capability (without expedited repair).

As shown in Fig. 22, quicker ILM deployment and setup would improve performance considerably. The peak NFMC degradation on day 7 in the base case would be halved.

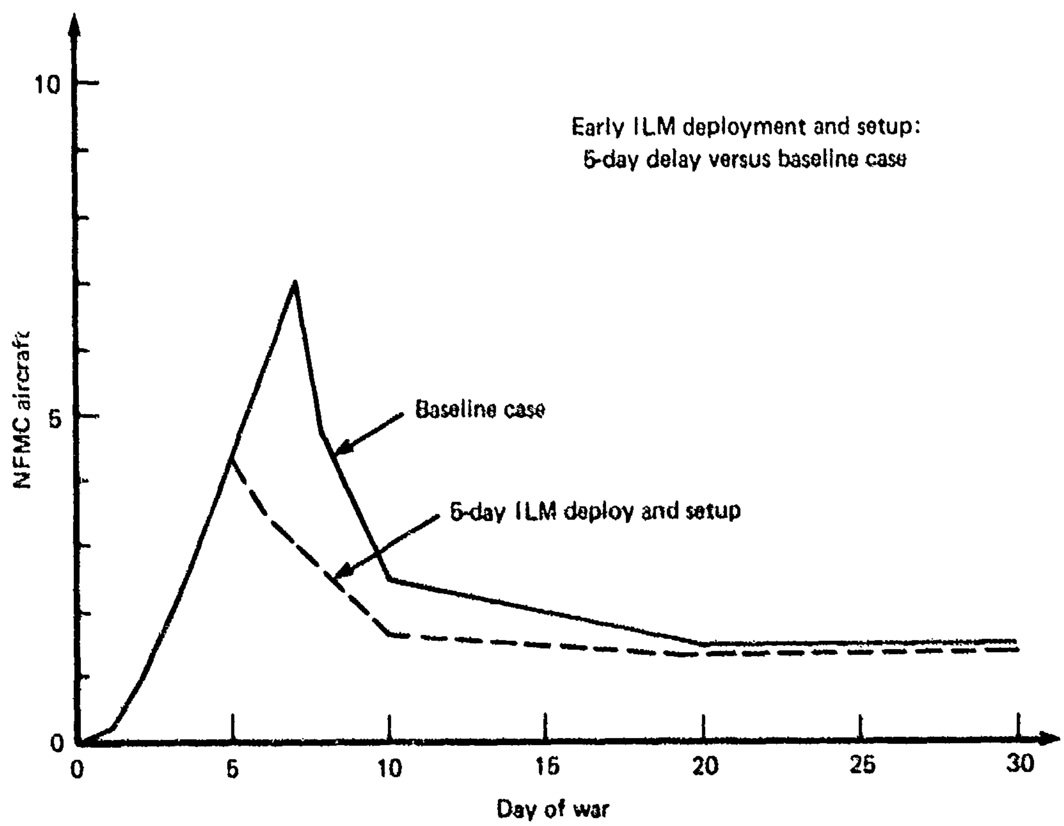

Fig. 22 -- Effects of quicker ILM deployment on aircraft availability

Reducing ILM Deployment Time with Centralized Repair

An alternative way to provide earlier ILM support is through a stationary facility that does not deploy with the unit. For example, a CIRF could provide continuous repair to the deployed unit. For our analysis of this option we considered a CIRF that could support the unit with only a one-day (each way) transportation delay.

As shown in Fig. 23, that option would improve wartime capability only slightly on day 7, and it would degrade wartime capability later. Thus the CIRF option is not very attractive in this case. In other, more realistic scenarios with multiple bases, this option may be more attractive.

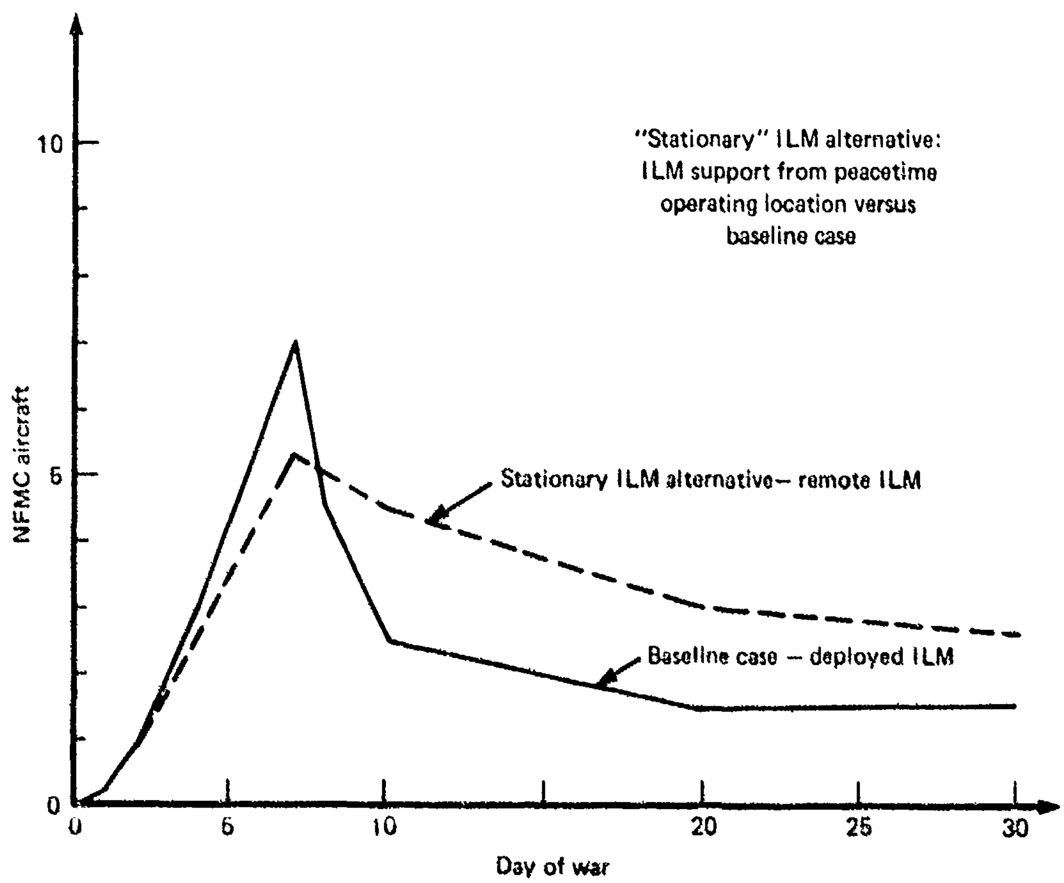

Fig. 23 -- Effects of a CIRF on aircraft availability

Increasing Stock Levels

The model supports several strategies for computing additional stock levels to improve aircraft availability. As described in Sec. III, two substrategies permit the model to compute stock needed to approach an NFMC target either for individual components or across the entire range of components. In addition, the information in the problem parts report can be used manually to construct a marginal increment to existing stock, essentially buying out[6] any component shortages to achieve a target NFMC.

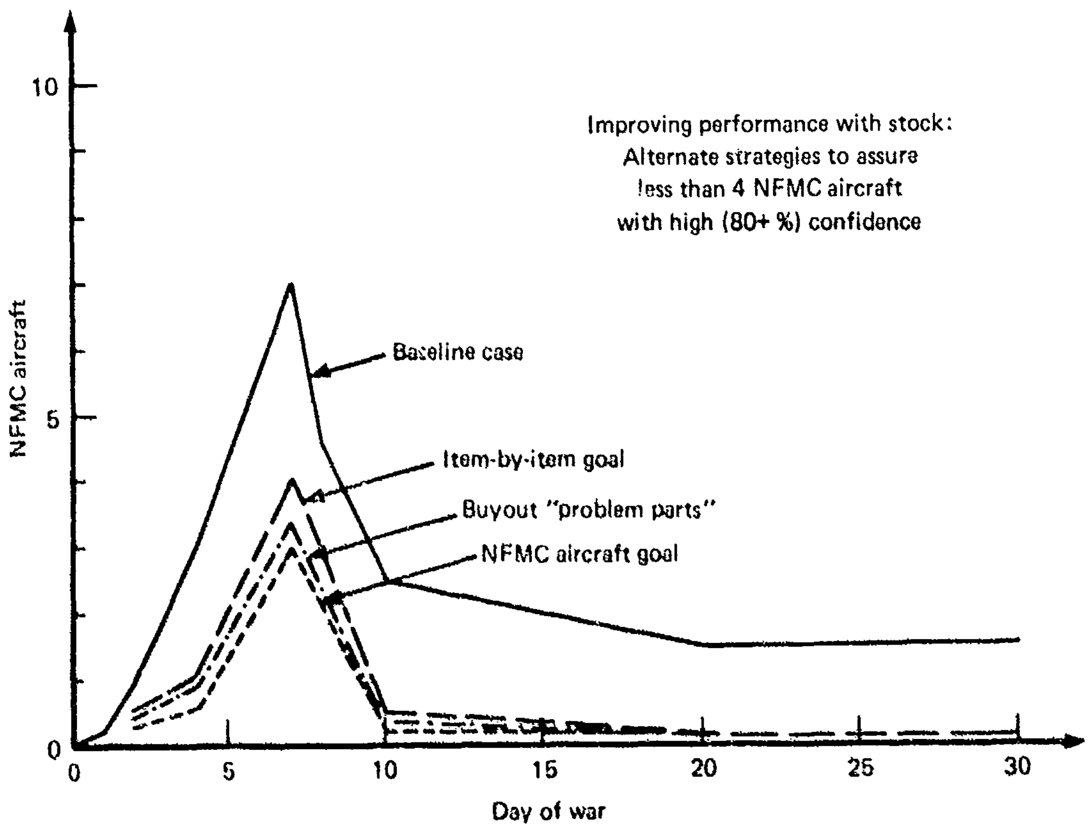

Fig. 24 -- Effects of alternative stockage computation strategies

[6] Buying enough spares to match the worst expected total pipeline quantity.

In our example, all three methods yield roughly similar performance on day 7 (Fig. 24), approximately meeting the goal of three or fewer NFMC aircraft (15 percent of 24 aircraft). But neither the item-by-item stockage nor the problem parts buyout actually achieved the goal. The item-by-item computation missed by a substantial margin, and although the problem parts buyout came closer to the goal, it was somewhat more expensive than the marginal analysis computation across the entire range of components.

The model documents the results of its internal stockage computations in two reports: a stockage cost analysis report at the end of the primary output, and a detailed stockage recommendation.

The stockage cost analysis report contains a description of the running total marginal cost of the model's suggested stockage actions at each time of analysis, and it reports the total cost of input stock. When we asked the model to achieve the NFMC target across all parts, it suggested that we purchase about $40,000 worth of stock to meet the performance goals on day 4, and an additional $310,000 to meet the goals on day 7 (a total of $350,000), as shown in Fig. 25. No additional stock was needed to meet the goals after day 7. Thus the model recommended adding some stock to the original $570,000 of input stock.

The detailed stockage recommendation is automatically formatted to be entered into a subsequent Dyna-METRIC performance analysis (Fig. 26); only the report's headings need be deleted. That report indicates the total stock needed to meet the target performance at all times of analysis.

How to Analyze Longer Wars

To analyze performance over a long period of time, the model can be recompiled with changed array-size parameters, or its time scale can be compressed by manipulating its input parameters.

Internally, the model does not know a day from a fortnight or a microsecond. Thus, if the time-sensitive input parameters are consistently scaled, a "day" can be interpreted as any convenient increment of time. To properly compress time, demands (i.e., sorties), deployment and setup times, cutoff times, repair times, transportation

COST OF PURCHASED STOCK IN MILLIONS OF DOLLARS:

Total Cost	4 DAY	7 DAY	10 DAY	20 DAY	30 DAY
LOC1	0.04	0.35	0.35	0.35	0.35
Sum Over All:	0.04	0.35	0.35	0.35	0.35

Base Pipeline:	4 DAY	7 DAY	10 DAY	20 DAY	30 DA
LOC1	0.04	0.35	0.35	0.35	0.35
Sum Over All:	0.04	0.35	0.35	0.35	0.35

COST OF INPUT STOCK IN MILLIONS OF DOLLARS:

Total Cost	0 DAY
LOC1	0.57
Sum Over All:	0.57

Base Pipeline:	0 DAY
LOC1	0.57
Sum Over All:	0.57

Fig. 25 -- Stockage cost analysis report

STOCK PURCHASED AT TIME 30

	LOC1
1430000435192BF	1
1430000780463BF	3
1430001114411BF	1
1430001117990BF	2
1430001458910BF	5
1430001830955BF	5
1430001834016BF	1
1430001834082BF	3
1430001946460BF	14
1430002356325BF	8

Fig. 26 -- Detailed stockage recommendation

times, and resupply times must be stated in the same units. In a run with our simple problem, we compressed time by a factor of seven, so that each "day" represented a week. Thus we stated the weekly sorties as demands, and the process times in weeks and fractions.

Except for some loss in fine detail, the compressed run provided the same performance as the baseline case without time compression (Fig. 27).

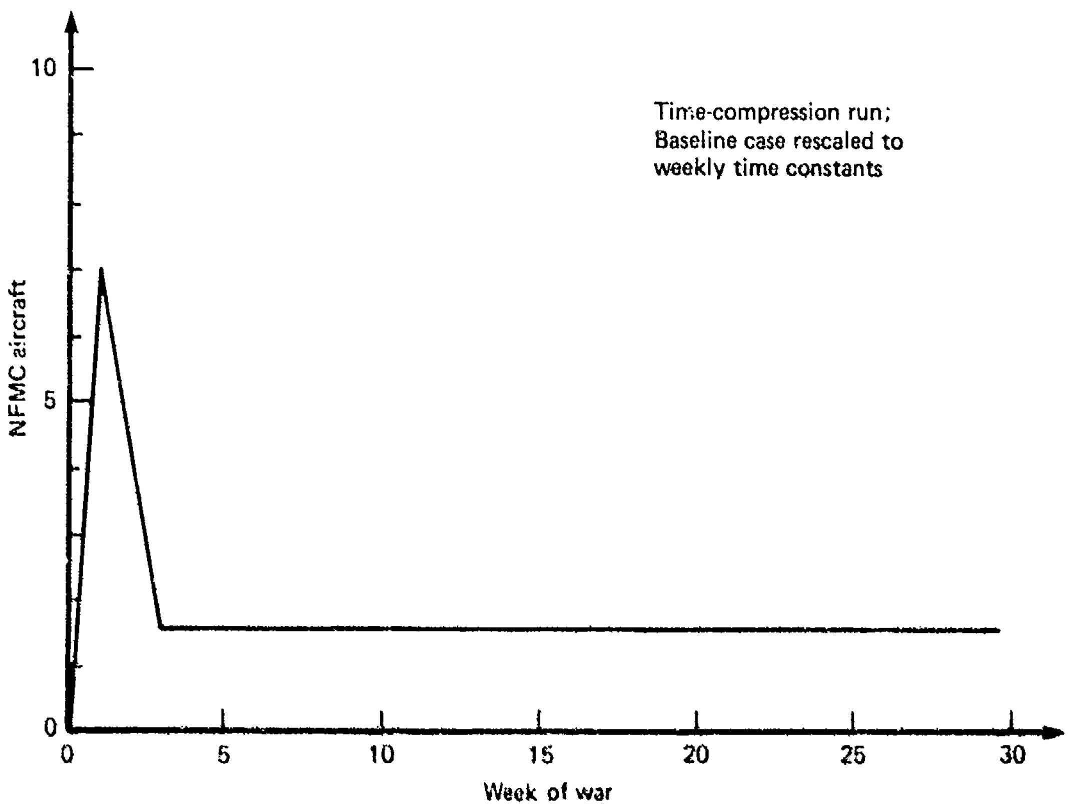

Fig. 27 -- Weekly (time-compression) analysis of example

Bootstrapping Dyna-METRIC Runs

Information from the time-compression run can help answer the question, What would happen if the unit was redeployed after six months of wartime operations? In this case, the pipelines in the time-compression run were saved on week (day) 26 and used to initialize the baseline example (instead of using zero flying as initial conditions).

As might be expected, redeploying the unit with some components already in repair (and some aircraft already NFMC) causes wartime capability to degrade compared to the base case (Fig. 28).

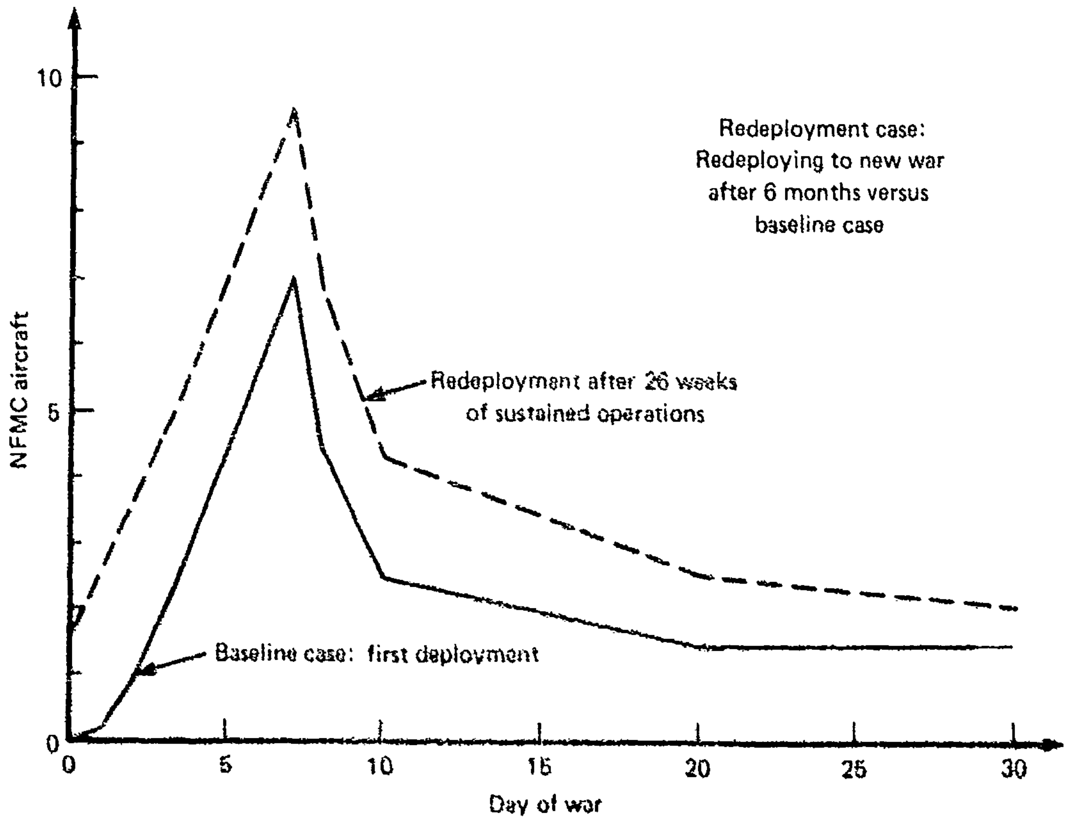

Fig. 28 -- Effect of prior activities on aircraft availability

Estimating the Effects of Constrained Repair with Test Equipment

As described in Sec. III, the model usually assumes that ample repair capacity will exist to meet the specified average repair time for each component. To assure that sufficient repair capacity does indeed exist, one can use the model's test-equipment feature to estimate the effects of critical repair resource constraints.

In our example, we assumed that the critical repair resources for these 10 components consisted of five identical test stations (with associated personnel, tools, diagnostic equipment, etc.). We assumed that the test-station technology was relatively simple and reliable, so that it never failed and never required periodic maintenance. Further, we assumed that sufficient personnel were assigned to the squadron to maintain a three-shift operation throughout the 30-day initial deployment scenario.

This information was communicated to the model in three blocks that constitute the test equipment description section of the problem description (Fig. 29). The first (TEST) block identifies the type of test equipment (STAT), specifies its unit cost ($100,000), and indicates the fraction of time it can test and repair components for various levels of colocated test stations (always 1.0 in this example for 1, 2, 3, 4, or 5 test stations). The second test-station beddown (TBED) block indicates the rate at which unstocked demands (backorders) arise for a test stand at each location (0.0), the resupply time for components to fix the test stand (0.0), resupply cutoff start and finish times (0.0 and 0.0, respectively),[7] and the scenario for test-stand deployment and setup at each base (no test stands operating until day 8; five test stands on day 8 and thereafter).[8] The third and final (TPRT) block indicates which components are tested and repaired at the test equipment (all of the components on our aircraft).

As might be expected, the long period without ILM creates a considerable backlog for the test stations (Fig. 30). Initially, the test stations give priority attention to the worst component, so they provide a rapid initial improvement in NFMC status by day 10. But that priority repair requires delaying repair of other components, so several

---

[7] These data are required to model more complex repair facilities, such as ATE. The daily backorder rate is the rate at which the test stand fails and cannot be repaired immediately. The resupply time, resupply cutoff, start, and finish permit one to model the time-dependent effects of changing test-stand support on aircraft availability.

[8] The 99 indicates that five test stands are available for the rest of the scenario

```
TEST
STAT     100000.  1.0  1.0  1.0   1.0  1.0
TBED
LOC1   0.0 0.00.00.0  0  8  5  99
TPRT
1430000435192BF
1430000780463BF
1430001114411BF
1430001117990BF
1430001458910BF
1430001830955BF
1430001834016BF
1430001834082BF
1430001946460BF
1430002356325BF
```

Fig. 29 -- Test-station description

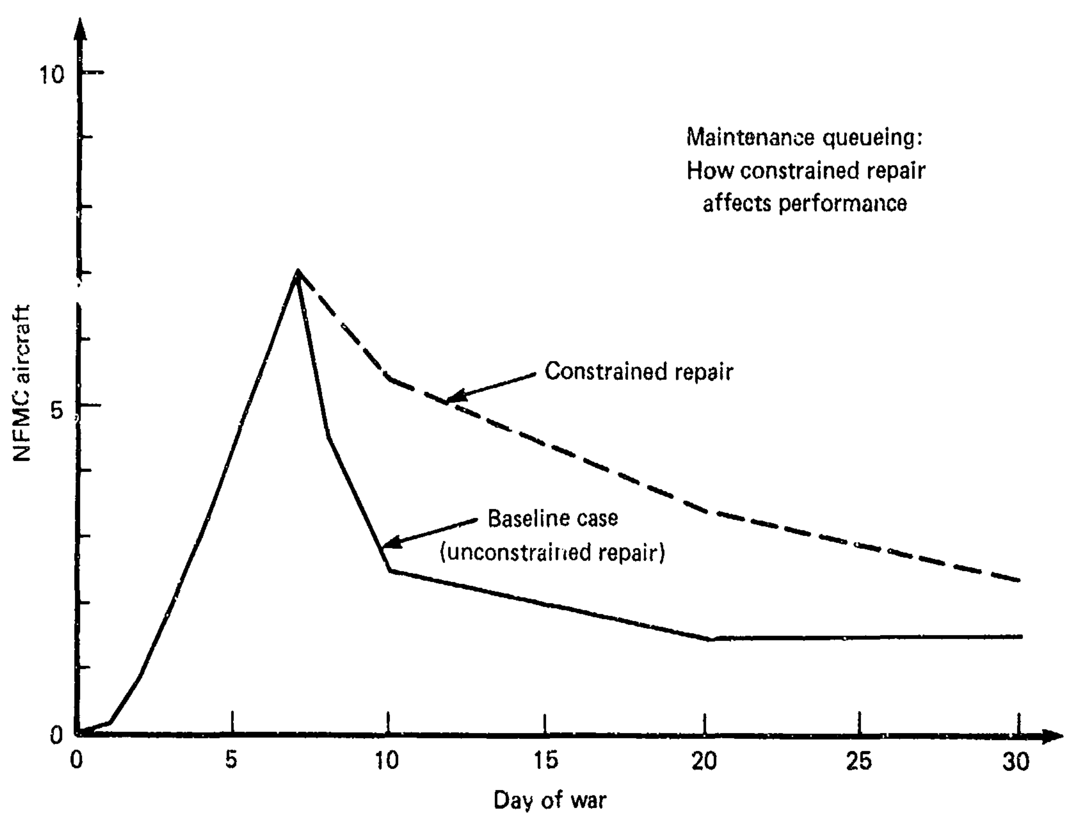

Fig. 30 -- Effect of repair-resource constraints on aircraft availability

parts jointly contend for repair priority by day 10, as shown by that day's problem parts list (Fig. 31). All three components would have two to four backorders (serviceable stock of -1.9 to -3.4), so further reductions in NFMC aircraft will require working on all three components, not just the worst one. Thus, the repair-capacity constraint in this example would prevent the system from achieving the performance of the baseline case.

ISOLATED BASE PROBLEM LRUS:

LOC1: PROBLEM LRUS:	STOCK LEVEL	SERV. STOCK	REP. ON HAND	REP. OFF BASE
1430001946460BF	10	-2.8	12.7	0.1
1430002356325BF	2	-3.4	3.9	1.4
1430001834082BF	2	-1.9	3.9	0.0

Fig. 31 -- Constrained-repair problem parts list on day 10

GETTING STARTED WITH DYNA-METRIC

The example described in this section is only a toy problem intended to demonstrate the model's basic operation. But it is also a good vehicle for one's first exploration of the model's capabilities. The data requirements of this problem are reasonably small, so they can be entered manually. The output reports can be compared to those shown here to verify that the model is operating properly and that the data were correctly entered. By entering this simple problem and making some excursions (even beyond those described above), one can quickly understand the model and judge its usefulness for logistics analyses.

After some experience with this toy problem, some readers may wish to apply the model to a real problem. If the problem is small (i.e., if there are relatively few components and subcomponents), the data may be gathered and entered manually. For larger problems, more reliable component and subcomponent data files (i.e., data with fewer typographic errors) should be gathered from automated sources.

Appendix A

PROBLEM DESCRIPTION INPUT FORMATS

A Dyna-METRIC problem description input file is conceptually divided into six major sections, each containing several "blocks" of data. Blocks are delimited by distinct block markers that indicate the nature of the following data. Block markers' names have special meaning to the system and should not be used to name bases, CIRFs, components, subcomponents, or test equipment types. Each block marker is a record containing a four-character name. Only the STK block marker contains any other data.

The six major sections of data are listed below, together with the block markers associated with each section and the type of data entered in each block. The record formats for each type of data follow this listing.

I. Administrative Data:

```
        Title
        Assumptions and Mission Description
        Times of Analysis
        OPT Block
                Options
```

II. Operational and Support Scenario Data:

```
        CIRF Block if CIRFs are to be used
                CIRF Scenario (one per CIRF)
        BASE Block
                Base Scenario (one per base)

        Any or all of the following blocks (in any order desired):

            ACFT Block
                Aircraft Level (one per base)
            SRTS Block Marker
                Sortie Rate (one per base)
            FLHR Block Marker
                Flying Hours per Sortie (one per base)
            ATTR Block
                Aircraft Attrition Rate (one per base
                    with non-zero attrition)
```

MESL Block
    Mission Requirements (one per base
        not flying all mission types)
TURN Block
    Maximum Sortie Rate (one only)
Note: The TURN Block is required

End of optional groups

III. Component Description Data:

LRU Block
    LRU Description
APPL Block
    Mission Essentiality and Application Fraction
Note: APPL cards need to be entered only for those
    components not applicable to all missions or not
    applicable to all aircraft at some location.

IV. Subcomponent Description Data:

SRU Block
    SRU Description
followed by:
INDT Block
    LRU-SRU Relationship

V. Test Equipment Description:

If Test Equipment is to be modeled, include one copy of
    the following three blocks for each test stand type:
    TEST Block
        Test Equipment Cost and Availability
    The following groups may appear in either order, but
        both are required:
        TPRT Block
            LRUs Tested
        TBED Block
            Test Stand Beddown

VI. Stock-Level data:

The following block (including the Block Marker) may be
    entered multiple times to change input stock
    over the duration of the scenario:
    STK Block (if stock levels are to be read in)
        Stock Level
    Note: Stock may be incremented, decremented, or wholly set
        anew any time in the scenario. Therefore the STK
        block marker has two parameters: the time at which

stock levels change, and whether an incremental, decremental, or override change is specified by the following stock data. The format of the STK block marker is:

Columns	Internal Fortran Name	Description
1- 4	STK	
17-19	STKTIM	Time at which stock changed (zero or blank for initial stock
21-22	ADDIT	Additive indicator (1 = increment, 0 = override, -1 = decrement)

VII. End of Problem

The last item in the problem description:
END

Record formats for each type of data are shown on the following pages.

Title

Columns	Format	Internal Fortran Name	Description
1-80		HEAD	Title to be printed at the top of the main report.

Note: A title must appear as the first line of a Dyna-METRIC input file, even if the title is totally blank.

Assumption and Mission Description

Columns	Format	Internal Fortran Name	Description
1- 2	xx	IRAN	Random Repair Time Flag (0 => deterministic) (1 => exponential). This specifies whether repair times, transportation times, and AWP delays will be constant or exponentially distributed.
3- 7	xx.xx	ADMINB	Base Administrative Delay (days). This delay (always deterministic) is used to model the time which passes after an LRU is removed from an aircraft at the flight line until it arrives at the repair facility.
8-12	xx.xx	ADMINC	CIRF Administrative Delay (days). This delay (always deterministic) is used to model the time which passes after an LRU or SRU arrives at the CIRF until it is moved to the CIRF repair facility.
13-32			(reserved)
33-35	xxx	MSNLBL	Mission Label for mission type 1.
36-38	xxx	MSNLBL	Mission Label for mission type 2.
39-41	xxx	MSNLBL	Mission Label for mission type 3.
42-44	xxx	MSNLBL	Mission Label for mission type 4.
45-47	xxx	MSNLBL	Mission Label for mission type 5.

Note: The maximum number of mission types is chosen when the model is compiled, but we recommend that five mission types be allowed. If one deviates from five mission types, the Application Fraction data format will change (e.g., to allow more mission types).

Times of Analysis

Columns	Format	Internal Fortran Name	Description
1- 4	xxxx	MXTMS	Day for which Analysis is Requested (first) (e.g., 5 -- output status at the end of the fifth day of combat)
5- 8	xxxx		Time Value (second)
9-12	xxxx		(third)
13-16	xxxx		(fourth)
17-20	xxxx		(fifth)
21-24	xxxx		(sixth)
25-28	xxxx		(seventh)
29-32	xxxx		(eighth)
23-36	xxxx		(ninth)

Note: A maximum of nine time values are allowed. These times may be specified in any order. The order should not affect run time, but it may affect the stock mix if options 4 or 7 are invoked (i.e., if cross-component stockage is requested).

Options

Columns	Format	Internal Fortran Name	Description
5- 7	xxx	OPT	Option Number
8-10	xxx	ONMCS	First Option Parameter
11-15	xx.xx	OPROB	Second Option Parameter

The options available in Dyna-METRIC are:

1. Print a warning message if demanded sorties cannot be achieved with the confidence level (0 to 100 percent) specified in the second parameter.

2. Add enough CIRF stock for each component (LRU) to assure (with the confidence specified in the second parameter) that fewer CIRF-served aircraft than a target percentage (specified in the first parameter) are degraded for that part due to CIRF repair and retrograde transportation delays.

3. Add base stock for each component (LRU) to assure (with the confidence specified in the second parameter) that fewer base aircraft than a target percentage (specified in the first parameter) are degraded for that part due to base repair and serviceable-component transportation delays.

4. Cost-efficiently add base stock across all components (LRUs) to assure (with the confidence specified by the second parameter) that fewer base aircraft than a target percentage (specified in the first parameter) will be degraded for any component due to base repair and serviceable-component transportation delays.

5. Add enough test equipment to repair the reparable-component backlog (assuming new test equipment can be deployed and set up with the current first increment of test equipment).

6. Add base and CIRF stock for each subcomponent (SRU) to assure (with the confidence specified in the second parameter) that fewer base (and CIRF-served) aircraft than a target percentage (specified in the first parameter) will be degraded for component repair delays due to that subcomponent.

7. Add base and CIRF stock for all subcomponents (SRUs) to assure (with the confidence specified in the second parameter) that fewer base (and CIRF-served) aircraft than a target percentage (specified in the first parameter) will be degraded for component repair delays due to all subcomponents.

8. Identify the minimum number of problem components that, if fixed, would assure (with the confidence specified in the second

parameter) that fewer base aircraft than a target percentage (specified in the first parameter of option 11) will be degraded for component support. Limit the number of components to less than the first parameter.

9. When computing stock, print the resultant stock levels for each component and subcomponent at each time of analysis.

10. Initialize the peacetime pipelines from previously saved or measured data.

11. Print the predicted number of degraded aircraft (with and without cannibalization) and the predicted sorties accomplished at each time of analysis, based on the input (or previously computed) stock levels. Include the probability that fewer base aircraft than the target percentage (specified in the first parameter) will be degraded for component support.

12. Same as Option 11, but based on computed stock levels.

13. Do not echo any input data.

14. Do not echo any parts descriptive data.

15. Print a detailed parts disposition report at each time of analysis. If the first parameter equals 1, also print the detailed expected disposition of parts under test for each day of the scenario.

16. Save the pipeline status at the last time of analysis for initialization of follow-on runs.

CIRF Scenario

Columns	Format	Internal Fortran Name	Description
1- 4	xxxx	CNAME	CIRF Name
5-23			(reserved)
24-26	xx.	TD	ILM Deployment Period (days)
27-29	xx.	TS	ILM Setup Period (days). TD+TS is the time required for the deployment and setup of RRR[1] repair capability. If this capability is to be available from the start of the conflict, set both these parameters to zero.
30-32	xx.	TC	Beginning Day of CONUS Resupply of Wartime Demands (day). This is the day on which wartime orders placed on the depot by this CIRF can first start transit.
33-35	xx.	TDR	ILM Deployment Period for RR Items (days).
36-38	xx.	TSR	ILM Setup Period for RR Items (days). TDR+TSR is the time required for the deployment and setup of repair capability for RR coded items.
39	x	IC	CONUS Peacetime Pipeline Interruption Indicator (if IC=1, pipeline empties from day 1; if IC=0, pipeline empties from day TC)
40	x	SRUCAN	SRU cannibalization (1=full; 0=none). SRUs can only be cannibalized from the same type of LRU which is also AWP at the CIRF.
41-43	xx.	TSRU	Day on which SRU Repair Capability is Available. Between days 1 and TSRU-1, no SRUs are repaired.
44-46	xx.	TPSRU	Peacetime SRU Resupply Time (days).
47-49	xx.	T1SRU	Day on which SRU Resupply is Available (day). The first day on which wartime orders for SRUs by the CIRF from the depot may start transit.
50-52	xx.	T2SRU	CIRF Dependent Addition to SRU Order and Ship Time (days).
53-58			(reserved)
59-61	xx.	TDCO	First Day of Forward Transportation Cutoff from Depot to the CIRF.
62-64	xx.	TDCOD	Duration of Cutoff from Depot (days).

Note: The maximum number of CIRFs and bases is chosen when the model is compiled. There is no limit on CIRFs alone.

[1] RR (remove and replace) and RRR (remove, repair, and replace) are only convenient names to discriminate between two classes of components whose repair arrives at different times in the scenario. The model does not use these names to affect the repair process, except to indicate when repair capability arrives.

Base Scenario

Columns	Format	Internal Fortran Name	Description
1- 4	xxxx	BNAME	Base Name
6- 9	xxxx	CNAME	CIRF Name (if served by a CIRF). This field should be left blank if there is no CIRF. Otherwise, the name entered is checked against the list of CIRFs until a match is made.
10-13	xx.x	CBTRAN	Forward Transportation Time (CIRF to base) (days). This part of the transportation system is subject to cutoffs, as specified by TCCO and TCCOD below.
14-17	xx.x	BCTRAN	Retrograde Transportation Time (base to CIRF) (days).
18-23			(reserved)
24-26	xx.	TD	ILM Deployment Period (days).
27-29	xx.	TS	ILM Setup Period (days). TD+TS is the time required for the deployment and setup of RRR repair capability. If this capability is to be available from the start of the conflict, set both these parameters to zero.
30-32	xx.	TC	Beginning Day of CONUS Resupply of Wartime Demands (day). This is the day on which wartime orders can first be shipped from the depot.
33-35	xx.	TDR	ILM Deployment Period for RR Items (days).
36-38	xx.	TSR	ILM Setup Period for RR Items (days).
39	x	IC	CONUS Peacetime Pipeline Interruption Indicator (if IC=1, pipeline empties from day 1; if IC=0, pipeline empties from day TC)
40	x	SRUCAN	SRU cannibalization (1=full; 0=none). SRUs can only be cannibalized from identical LRUs already AWP at the base.
41-43	xx.	TSRU	Day on which SRU Repair Capability is Available. Between days 1 and TSRU-1, no SRUs are repaired.
44-46	xx.	TPSRU	Peacetime SRU Resupply Time (days).
47-49	xx.	T1SRU	Day on which SRU Resupply is Available.
50-52	xx.	T2SRU	Base dependent addition to SRU Order and Ship Time (days).
53-55	xx.	TCCO	First Day of Forward Transportation Cutoff from CIRF to the Base.
56-58	xx.	TCCOD	Duration of Cutoff from CIRF (days).
59-61	xx.	TDCO	First Day of Forward Transportation Cutoff from Depot to the Base.
62-64	xx.	TDCOD	Duration of Cutoff from Depot (days).

Note: The maximum number of CIRF and bases is chosen when the model is compiled. There is no limit on bases alone.

Aircraft Level

Columns	Format	Internal Fortran Name	Description
1- 4	xxxx	BNAME	Base Name
5- 8	xxx.	ACFTP	Peacetime Aircraft Level
9-12	xxxx	ITIM	Day at which Aircraft Level Changes
13-16	xxx.	ACTFW	New Aircraft Level (second)
17-20	xxxx	ITIM	Day at which Aircraft Level Changes (second)
21-24	xxx.	ACFTW	(third)
25-28	xxxx	ITIM	
29-32	xxx.	ACFTW	(fourth)
33-36	xxxx	ITIM	
37-40	xxx.	ACFTW	(fifth)
41-44	xxxx	ITIM	
45-48	xxx.	ACFTW	(sixth)
49-52	xxxx	ITIM	
53-56	xxx.	ACFTW	(seventh)
57-60	xxxx	ITIM	
61-64	xxx.	ACFTW	(eighth)
65-68	xxxx	ITIM	
69-72	xxx.	ACFTW	(maximum of 9 Aircraft Levels allowed)
73-76	xxxx	ITIM	

Note: Any base not having an Aircraft Level card is assumed to have zero aircraft throughout the scenario.

Sortie Rate

Columns	Format	Internal Fortran Name	Description
1- 4	xxxx	BNAME	Base Name
5- 8	xx.x	SORTSP	Peacetime Sortie Rate
9-12	xxxx	ITIM	Day at which Sortie Rate Changes
13-16	xx.x	SORTSW	New Sortie Rate (second)
17-20	xxxx	ITIM	Day at which Sortie Rate Changes (second)
21-24	xx.x	SORTSW	(third)
25-28	xxxx	ITIM	
29-32	xx.x	SORTSW	(fourth)
33-36	xxxx	ITIM	
37-40	xx.x	SORTSW	(fifth)
41-44	xxxx	ITIM	
45-48	xx.x	SORTSW	(sixth)
49-52	xxxx	ITIM	
53-56	xx.x	SORTSW	(seventh)
57-60	xxxx	ITIM	
61-64	xx.x	SORTSW	(eighth)
65-68	xxxx	ITIM	
69-72	xx.x	SORTSW	(maximum of 9 Sortie Rates allowed)
73-76	xxxx	ITIM	

Note: Any base not having a Sortie Rate card is assumed to be flying no sorties throughout the scenario.

Flying Hours per Sortie

Columns	Format	Internal Fortran Name	Description
1- 4	xxxx	BNAME	Base Name
5- 8	xxx.	FHSRTP	Peacetime Flying Hours per Sortie
9-12	xxxx	ITIM	Day at which Flying Hours per Sortie changes
13-16	xxx.	FHSRTW	New Flying Hours per Sortie (second)
17-20	xxxx	ITIM	Day at which Flying Hours per Sortie changes (second)
21-24	xxx.	FHSRTW	(third)
25-28	xxxx	ITIM	
29-32	xxx.	FHSRTW	(fourth)
33-36	xxxx	ITIM	
37-40	xxx.	FHSRTW	(fifth)
41-44	xxxx	ITIM	
45-48	xxx.	FHSRTW	(sixth)
49-52	xxxx	ITIM	
53-56	xxx.	FHSRTW	(seventh)
57-60	xxxx	ITIM	
61-64	xxx.	FHSRTW	(eighth)
65-68	xxxx	ITIM	
69-72	xxx.	FHSRTW	(maximum of 9 Flying Hours per Sortie allowed)
73-76	xxxx	ITIM	

Note: Any base not having a Flying Hours per Sortie card is assumed to fly one-hour sorties.

Aircraft Attrition Rate

Columns	Format	Internal Fortran Name	Description
1- 4	xxxx	BNAME	Base Name
5- 9	x.xxx	ATTR	Initial Aircraft Attrition Rate (per sortie)
10-13	xxxx	ITIM	Day at which Next Attrition Rate Changes
14-18	x.xxx	ATTR	Aircraft Attrition Rate (second)
19-22	xxxx	ITIM	Day at which Next Attrition Rate Changes (second)
23-27	x.xxx	ATTR	(third)
28-31	xxxx	ITIM	
32-36	x.xxx	ATTR	(fourth)
37-40	xxxx	ITIM	
41-45	x.xxx	ATTR	(fifth)
46-49	xxxx	ITIM	
50-54	x.xxx	ATTR	(sixth)
55-58	xxxx	ITIM	
59-63	x.xxx	ATTR	(seventh)
64-67	xxxx	ITIM	
68-72	x.xxx	ATTR	(maximum of 8 Aircraft Attrition Rates allowed)
73-76	xxxx	ITIM	

Note: Any base not having an Aircraft Attrition Rate card is assumed to have no attrition throughout the time period.

Mission Requirements

Columns	Format	Internal Fortran Name	Description
1- 4	xxxx	BNAME	Base Name
6-10	xxxxx	MISION	Initial Mission Types
11-13	xxx	ITIM	Day at which Mission Assignments Change
14-18	xxxxx	MISION	New Mission Assignments (second)
19-21	xxx	ITIM	Day at which Mission Assignments Change (second)
22-26	xxxxx	MISION	(third)
27-29	xxx	ITIM	
30-34	xxxxx	MISION	(fourth)
35-37	xxx	ITIM	
38-42	xxxxx	MISION	(fifth)
43-45	xxx	ITIM	
46-50	xxxxx	MISION	(sixth)
51-53	xxx	ITIM	
54-58	xxxxx	MISION	(seventh)
59-61	xxx	ITIM	
62-66	xxxxx	MISION	(eighth)
67-69	xxx	ITIM	
70-74	xxxxx	MISION	(maximum of 9 Mission Assignments allowed)
75-77	xxx	ITIM	

Note: Any base not having a Mission Requirements card is assumed to fly all missions throughout the time period.

Maximum Sortie Rate

Columns	Format	Internal Fortran Name	Description
1- 4	xx.x	TRATE	Initial Maximum Sortie Rate
5- 8	xxxx	ITIM	Day at which Maximum Sortie Rate Changes
9-12	xx.x	TRATE	New Maximum Sortie Rate (second)
13-16	xxxx	ITIM	Day at which Maximum Sortie Rate Changes (second)
17-20	xx.x	TRATE	(third)
21-24	xxxx	ITIM	
25-28	xx.x	TRATE	(fourth)
29-32	xxxx	ITIM	
33-36	xx.x	TRATE	(fifth)
37-40	xxxx	ITIM	
41-44	xx.x	TRATE	(sixth)
45-48	xxxx	ITIM	
49-52	xx.x	TRATE	(seventh)
53-56	xxxx	ITIM	
57-60	xx.x	TRATE	(eighth)
61-64	xxxx	ITIM	
65-68	xx.x	TRATE	(maximum of 9 Maximum Sortie Rates allowed)
69-72	xxxx	ITIM	

Note: The Maximum Sortie Rate card is required. This number should represent the most sorties an FMC aircraft can fly in one day.

LRU Description

Columns	Format	Internal Fortran Name	Description
1-16		NASSY	Name of LRU. This name should be unique--not used for any other LRUs or SRUs, or for a block marker.
17-23	x.xxxxx	DDRP	Failures per Flying Hour (during peacetime). The expected number of LRUS per flying hour removed from an aircraft and sent to the shop by flight-line personnel.
24-28	x.xxx	FNRTS	Fraction NRTS at Base Not Supported by CIRF. The expected fraction of the LRUs removed at the base that the maintenance shop sends to the depot for repair.
29-33	x.xxx	BNRTS	Fraction NRTS at Base Supported by CIRF. The expected fraction of the LRUs removed at the base that the maintenance shop will send to the CIRF.
34-38	x.xxx	CNRTS	Fraction NRTS at CIRF. The expected fraction of LRUs received at a CIRF that will be sent to the depot for repair.
39-43	xx.xx	TTEST	Total Test Time or Repair Time (days). The expected time per LRU that the test equipment remains exclusively dedicated to the LRU. If the LRU is not assigned to a test stand, the expected time to repair or NRTS the LRU.
44-51	xxxxxxx.	COST	Cost of Item (dollars, or other convenient value).
52-53	xx	QPACFT	Quantity per Aircraft.
54-55	xx	RRR	Component ILM repair policy. Distinguishes between components with initial RRR (remove, repair and replace) ILM capability and components with only RR (remove and replace) ILM.[2]
56-57	xx	CIRFP	CIRF Part Designator (CIRFP=1 if sent to CIRF; CIRFP=0 if sent to Depot) specifies whether the CIRF is equipped to repair the LRU.
58-61	x.xx	LINEAR	Wartime Non-Linearity Failure Factor.
62-65	x.xx	VI	Variance to Mean Ratio (must be nonnegative; VI<1 if binomial; VI=1 if Poisson; VI>1 if negative binomial).
66-68	xxx	TOSTW	Wartime Order and Ship Time (days).
69-71	xxx	TOSTP	Peacetime Order and Ship Time (days).
72-76	x.xxx	RHO	Probability LRU cannot be repaired if test stand has a backorder.

[2] RR and RRR are only names used to distinguish between components whose repair capability arrives at different times in the scenario. The model repairs RR items once the appropriate repair capability is deployed to a base or CIRF.

Mission Essentiality and Application Fraction

Columns	Format	Internal Fortran Name	Description
1-16		PNAME	Part Name
18-22	xxxxx	MESL	Mission Essentiality Code left justified, in order of missions declared on Assumptions and Mission Description (for example, code 10100 means that the LRU is essential to the first and third mission but not the second, fourth, and fifth).
23-26	x.xx	APP	Application Fraction (first base)
27-30	x.xx	APP	Application Fraction (second base)
31-34	x.xx	APP	(third)
35-38	x.xx	APP	(fourth)
39-42	x.xx	APP	(fifth)
43-46	x.xx	APP	(sixth)
47-50	x.xx	APP	(seventh)
51-54	x.xx	APP	(eighth)
55-58	x.xx	APP	(ninth)
59-62	x.xx	APP	(tenth)
63-66	x.xx	APP	(eleventh)
67-70	x.xx	APP	(twelfth)

Note 1: Any LRU whose Mission Essentiality and Application data are not expressly entered is assumed to have an Application Fraction of 1.00 and to be essential for all Mission Types flown at all bases.

Note 2: The maximum number of bases and the maximum number of mission types are determined when the model is compiled. In usage to date, we have found that five missions were sufficient. Changing the maximum number of missions at compile time would change the format shown here (inserting or deleting columns in MESL, and shifting APP data right or left). We show here the format for five mission types and twelve bases.

Note 3: Application Fraction data must be entered for bases in the same order as they appear in the BASE block.

SRU Description

Columns	Format	Internal Fortran Name	Description
1-16		NASSY	Name of SRU
18-25	xxxxxxxx.	COST	Cost of SRU
26-28	xxx	QPACFT	Quantity per *aircraft* of SRU
29-36	xx.xxxxx	DDRW	Demands per Flying Hour for SRU (assumed to change in wartime with the same linearity factor as the parent LRUs.)
37-41	xx.xx	RTSRU	SRU Repair Time (days). This is the time required to repair the SRU or NRTS it.
42-43	xx	LOR	Level of Repair (1=Base or CIRF; 2=CIRF). If LOR is 1, the subcomponent can be repaired anywhere. If LOR is 2, the base cannot repair it, and the item is NRTS. If LOR is 2, only a CIRF or depot can repair the subcomponent.
44-48	x.xxx	SNRTS	Fraction NRTS.
49-51	xx.	SOSTB	SRU Order and Ship Time to a Base (days).
52-54	xx.	SOSTD	SRU Order and Ship Time to a CIRF (days).

Note: The quantity per *aircraft* is required in the SRU description. If the subcomponent appears on several different components or the component appears several times on the aircraft, this value will be different from the quantity per *application* used to describe LRU-SRU Relationships (next page). Error 111 (Appendix C) will arise if the LRU-SRU Relationship implies a different subcomponent quantity per *aircraft* than stated in the SRU Description.

LRU-SRU Relationship

Columns	Format	Internal Fortran Name	Description
1-16		NASSY	Name of LRU/SRU.
18-18	x	ID	LRU ('L')/SRU ('S') identifier. Used to specify whether the part is an LRU or an SRU.
19-21	xxx	QPLRU	Quantity per Application of this SRU on the associated LRU (blank for LRU cards).

Note 1: These data identify which subcomponents (SRUs) appear on each component (LRU). Each LRU (that has SRUs) appears on a single line, followed by a line for each SRU found on the LRU.

Note 2: LRUs *must* appear in same order as in the LRU block, though some may be omitted. SRUs *should* appear in the same order as in the SRU block.

Test Equipment Cost and Availability

Columns	Format	Internal Fortran Name	Description
1- 4	xxxx	TNAME	Test Equipment Type Name (e.g., RDR or ENGN)
6-15	xxxxxxxxxx	TEQCST	Cost of Test Equipment
16-20	x.xxx	ALPHA	Availability, the fraction of day the equipment is available to test LRUs (if 1 available).
21-25	x.xxx	ALPHA	Available to test LRUs (if 2 colocated).
26-30	x.xxx	ALPHA	Available to test LRUs (if 3 colocated).
31-35	x.xxx	ALPHA	(if 4 colocated)
36-40	x.xxx	ALPHA	(if 5 colocated)
41-45	x.xxx	ALPHA	(if 6 colocated)
46-50	x.xxx	ALPHA	(if 7 colocated)
51-55	x.xxx	ALPHA	(if 8 colocated)

Note 1: The maximum number of test-equipment types is determined at compile time, and may be changed. There is no maximum number of test equipments of a given type.

Note 2: Some test equipments' availability increases when more duplicate test equipments are colocated. If more equipments are colocated in the Test Equipment Beddown than availability data are entered, the model will use the availability data entered for the highest number of colocated equipments. (For example, if availability is entered for up to three colocated equipments and the test-equipment beddown calls for five colocated stands at one base, the model will assume that the five stands each have the same availability as three colocated stands.)

LRUs Tested

Columns	Format	Internal Fortran Name	Description
1-16		PNAME	LRU Name

Note: One line is entered for each component tested by a given test-equipment type. They appear immediately after the test-equipment cost and availability have been defined for that test-equipment type.

Test Stand Beddown

Columns	Format	Internal Fortran Name	Description
1- 4	xxxx	BNAME	Base/CIRF Name. Must be the name of either a base not served by a CIRF, or a CIRF. Bases served by CIRFs are not allowed to have test stands.
5-10	x.xxxx	TFAIL	Backorder Rate for Test Equipment (per day of operation). Expected number of test-equipment parts backordered for each day the station is active (i.e., whenever it is dedicated to testing/repairing LRUs or is itself being tested/repaired or maintained).
11-14	xxx.	TRST	Wartime Average Test Equipment Resupply Time (days).
15-17	xx.	TECO	Day of Test Equipment Resupply Cutoff at Base.
18-20	xx.	TECOD	Duration of Test Equipment Resupply Cutoff (days).
21-23	xxx	NTEQ	Test Equipment Level (first)--number of equipments of the given type initially installed at the base.
24-26	xxx	ITIM	Day at which Test Equipment Level Changes
27-29	xxx	NTEQ	New Test Equipment Level (second)
30-32	xxx	ITIM	Day at which Test Equipment Level Changes (second)
33-35	xxx	NTEQ	(third)
36-38	xxx	ITIM	
39-41	xxx	NTEQ	(fourth)
42-44	xxx	ITIM	
45-47	xxx	NTEQ	(fifth)
48-50	xxx	ITIM	
51-53	xxx	NTEQ	(sixth)
54-56	xxx	ITIM	
57-59	xxx	NTEQ	(seventh)
60-62	xxx	ITIM	
63-65	xxx	NTEQ	(eighth)
66-68	xxx	ITIM	
69-71	xxx	NTEQ	
72-74	xxx	ITIM	

Note 1: If a base or CIRF is omitted, a test-stand level of 0 is assumed.

Note 2: A maximum of nine test-stand levels are allowed.

Stock Level

Columns	Format	Internal Fortran Name	Description
1-16		pname	Part Name. This can be either an LRU or an SRU name.
17-19	xxx	OSTK	Stock Level (first location)
20-22	xxx	OSTK	Stock Level (second location)
23-25	xxx	OSTK	(third location)
26-28	xxx	OSTK	(fourth location)
29-31	xxx	OSTK	(fifth location)
32-34	xxx	OSTK	(sixth location)
35-37	xxx	OSTK	(seventh location)
38-40	xxx	OSTK	(eighth location)
41-43	xxx	OSTK	(ninth location)
44-46	xxx	OSTK	(tenth location)
47-49	xxx	OSTK	(eleventh location)
50-52	xxx	OSTK	(twelfth location)

Note 1: Stock levels of zero are set for parts not entered.

Note 2: Stock levels are entered for all locations in the same order as they appear in the CIRF and BASE blocks. CIRFs appear first, followed by bases.

Appendix B

FILES USED BY DYNA-METRIC

Dyna-METRIC uses several sequential files to enter, save, manipulate, and report component support-system behavior. Each file's purpose and contents are listed below. Their physical characteristics vary from installation to installation, depending on hardware and operating-system characteristics. In this list, we provide sufficient information for a programmer who is already familiar with a given computer system to install Dyna-METRIC. The three unformatted files are for internal model use, and their record length will vary depending on computer word size. The formatted files are for external (human) use, and their record lengths are noted. Immediately following the list is a table showing how various model subroutines act on each file.

Unit 1 - Unformatted. Used to pass pipeline and probability information from the pipeline and performance routines to the problem LRUs routines.

Unit 2 - Formatted, 35 columns. Used to enter explicit peacetime pipelines when Option 10 has been selected.

Unit 3 - Unformatted. Used to pass pipeline information from subroutine Stkbs1 (which determines base-level pipelines) to subroutine Stkbs2 (which buys stock to cover the pipelines.)

Unit 4 - Unformatted. Used to pass SRU pipeline information from subroutines Srubas and Srucrf (through subroutines Stkbs1 and Stkcrf) to subroutine Stksru (which buys stock to cover the pipelines.)

Unit 5 - Formatted, 80 columns[1]. Standard Dyna-METRIC input stream.

Unit 6 - Formatted, 132 columns[2]. Standard Dyna-METRIC reports.

Unit 8 - Formatted, 132 columns. Additional, detailed pipeline and backorder information.

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[1] Minimum; longer record lengths are needed if more than nine values of attrition (ATTR block) are entered.

[2] Typical, but may be exceeded if there are more than ten bases in the scenario, and a problem parts report is requested.

Unit 9 - Formatted, 49 columns. Pipeline values are written out to file 9 when Option 16, the restart option, has been selected. This file may be reformatted by another routine and input on unit 2 in a subsequent run in order to restart the model.

Routine/ Subroutine	File 1			File 2			File 3			File 4			File 5			File 6			File 8			File 9		
	Read	Write	Rewind	Read	Write	Rewind	Read	Write	Rewind	Read	Write	Rewind	Read	Write	Rewind	Read	Write	Rewind	Read	Write	Rewind	Read	Write	Rewind
n .						X											X							
c.tupd																				X				
echo																	X							
lmbbas		X		X													X			X			X	
lmbcrf		X		X													X			X			X	
outp																	X							
perf		X															X			X				
prblst																	X							
problm	X		X														X							
rdprt													X											
rdscn													X											
rdstk													X							X				
rdtop													X				X							
rdtst													X				X							
srubas				X													X						X	
srucrf				X													X						X	
stkbs1								X	X		X						X			X				
stkbs2							X		X								X							
stkcrf											X									X				
stkprn																				X				
stksru										X		X												
stkteq				X													X							
stopit																	X							
teqbas		X		X													X			X			X	
teqcrf		X		X													X			X			X	

Appendix C

ERROR AND WARNING MESSAGES

As Dyna-METRIC first analyzes a problem description, it tests for several common data inconsistencies. Those inconsistencies are classified into two categories: errors and warnings. Errors represent one of four basic inconsistencies in the problem description:

1. Essential data are missing.
2. The problem exceeds compiled maximum limits.
3. Data appear out of sequence.
4. Some data show an impossible value.

Warnings represent only the presence of additional, inconsequential data in the problem description. Practically, the model will abort only if an error is detected (after printing the problem description); it will ignore the inconsequential data if a warning is detected. Both errors and warnings (if any) appear on the first page of the primary output file.

ERROR AND WARNING MESSAGES

Number	Message	Meaning
3	Error	After reading the base and CIRF scenario specifications and the transportation increment specifications, there should be a ACFT, SRTS, FLHR, ATTR, MESL, TURN, or LRU block marker. None of these was found.
5	Error	Too many bases appeared in the BASE block. No more than DMBASE* are allowed.
6	Error	Too many bases and CIRFs appeared in the BASE and CIRF blocks. No more than DMBASE* are allowed.
7	Error	Too many CIRFs have appeared in the CIRF block. No more than DMBASE* are allowed.
9	Error	The OPT block, which must follow the time of analysis, is missing.
11	Error	Too many aircraft have been assigned to a base during peacetime. No more than DMAIRCFT* are allowed.
12	Error	The CIRF specified in a base scenario does not match any of the CIRFs defined previously.
14	Error	Too many aircraft have been assigned to a base for some period during wartime. No more than DMAIRCFT* are allowed.
15	Error	No LRU description data have been entered. At least one such card is required.
16	Error	Too many LRUs have appeared in the LRU block. No more than DMLRUS* are allowed.
17	Error	Too many SRUs have been related to a given LRU in the INDT block. No more than DMSRULRU* are allowed.
18	Error	Too many SRUs have appeared in the SRU block. No more than DMSRUS* are allowed.
19	Error	An INDT block has been encountered in the SRU block. The INDT block is illegal if SRUs are not present.
20	Error	(a) Duplicate ACFT, SRTS, FLHR, ATTR, MESL, TURN, APPL, or SRU block has been found. Only one is allowed.

(b) Duplicate TPRT or TBED data has been found for the same type of test equipment. Only one is allowed per test-stand type.

21	Error	Too many LRUs have been assigned to a single type of test equipment. Only DMLRUTEQ* are allowed.
22	Error	Too many test-equipment types have appeared in the TEST block. Only DMTEQTYP* are allowed.
23	Error	A requested time of analysis is too large. The largest time of analysis allowed in version 3.04 is two less than DMTIME*.
67	Error	An SRU has been detected in the SRU block that has the same name as some LRU previously defined. Each part must have a unique name.
68	Warning	Two SRUs with the same name have been detected in the SRU block. Each SRU must have a unique name. Only data from the first occurrence will be used.
70	Error	The last block in the deck should be the STK block, followed by an END block marker. The STK block is optional. Neither the STK nor END block marker was found after the previous data had been read in.
71	Error	An unrealistic (negative or zero) repair time has been encountered for some LRU. The repair time must be positive.
72	Error	An unrealistic (negative or zero) wartime order and ship time has been encountered for some LRU. The order and ship time must be positive.
73	Error	An unrealistic (negative or zero) peacetime order and ship time has been encountered for some LRU. The order and ship time must be positive.
75	Error	LRUs must have unique names. Two LRUs with identical names have been encountered in the LRU block.
80	Error	The LRUs Tested (TPRT block) has not been included for some type of test equipment. These data are required.
81	Error	The Test Stand Beddown (TBED block) has not been included for some type of test equipment. These data are required.
82	Error	A base with some Mission Requirements (MESL block) does not match any of the bases defined previously in BASE block.

83	Error	After the Mission Requirements (MESL block) for each base not flying all mission types, there should be a block marker to indicate what the next block of data is. That block marker is missing.
84	Error	A base named with Flying Hours per Sortie (FLHR block) does not match any of the bases defined previously in the BASE block.
85	Error	After the Flying Hours per Sortie (FLHR block) for each base, there should be a block marker to indicate what the next block of data is. That block marker is missing.
88	Error	A test-stand beddown specification has been entered for a base that is served by a CIRF. Test equipment may only be stationed at CIRFs and at bases that are not served by CIRFs.
89	Error	The base or CIRF named in a Test Equipment Beddown (TBED block) does not match any of the bases or CIRFs defined previously in the BASE and CIRF blocks.
90	Error	After the Mission Essentiality and Application Fraction for each LRU that is not applicable to all missions and all aircraft at all missions, there should be a block marker to indicate what the next block of data is. That block marker is missing.
93	Error	A base named with an Aircraft Level (ACFT block) does not match any of the bases defined previously in the BASE block.
94	Error	After the Aircraft Level (ACFT block) for each base, there should be a block marker to indicate what the next block of data is. That block marker is missing.
95	Error	A base with a Sortie Rate (SRTS block) does not match any of the bases defined previously in the BASE block.
96	Error	After the Sortie Rate (SRTS block) for each base, there should be a block marker to indicate what the next block of data is. That block marker is missing.
97	Error	A base with an Aircraft Attrition Rate (ATTR block) does not match any of the bases defined previously in the BASE block.
98	Error	After the Aircraft Attrition Rate (ATTR block) for each base with nonzero attrition, there should be a block marker to indicate what the next block of data is. That block marker is missing.

99	Error	An impossible option has been requested. Only options 1 through 16 are defined.
103	Error	The LRU named in an LRU-SRU Relationship does not match any of the LRUs previously defined in the LRU block.
104	Error	The SRU named in an LRU-SRU Relationship does not match any of the SRUs previously defined in the SRU block.
107	Warning	An LRU or SRU has a stock level but does not appear in the LRU or SRU blocks.
108	Error	(a) An LRU with a Mission Essentiality and a Application Fraction (APPL block) does not appear in the LRU block. (b) An LRU tested by a test equipment (TPRT block) does not appear in the LRU block.
110	Error	A component or subcomponent has been encountered in the INDT block with an illegal LRU/SRU identifier. That identifier must be either L or S.
111	Error	A quantity per aircraft was input for each SRU in the SRU block. The LRU-SRU relationship (INDT block) indicates how many SRUs there are per LRU. If the INDT block data (across all LRUs on the aircraft, including those whose QPA exceeds 1) are inconsistent with the SRU data, there is a data error.
112	Error	An SRU has been related to too many LRUs in the INDT block. Only DMSRULRU* are allowed.
113	Warning	An SRU appears in the SRU block that is not related to an LRU in the INDT block. That SRU will be ignored.

*Defined at compile time. Can be adjusted when the model is recompiled at the user site.

STOP CODES

Number	Meaning
20	An input error was encountered somewhere in the input stream. Specific error messages will have been written at the top of the report describing the problem.
30	Too many aircraft were encountered. Probable causes: (1) Input number of aircraft for some base and time of analysis exceeded DMAIRCFT. (2) A negative attrition rate was entered, which increased the number of aircraft to too high a level. Possible remedies: (1) a. Input fewer aircraft. b. Increase DMAIRCFT and recompile model. (2) Remove the negative attrition rate.
31	Too many LRUs of a given type were encountered. Probable causes: (1) For some LRU at some time of analysis, the quantity per aircraft times the number of aircraft at a base plus the amount of input stock of that LRU at that base is greater than or equal to DMPMFMAX. (2) During a stockage computation, enough stock was added by the stock-purchasing algorithm to create the problem described above. Possible remedies: (1) Input less stock. (2) Increase DMPMFMAX and recompile model. (3) Use fewer aircraft. (4) In the stockage computation, request either a lower goal or a lower confidence level.
32	An impossible value was detected in the pipeline distribution. Probable cause: A negative variance-to-mean ratio was read in for some LRU. Possible remedy: Change the variance-to-mean ratio to a nonnegative value.

33 An impossible value was detected in the backorder distribution.

Probable causes:

(1) A negative level of stock was input for some LRU.

(2) When using the facility to delete stock from the initial input levels at some later time, more stock was deleted than was originally read in.

Possible remedies:

(1) Read in nonnegative stock levels.

(2) Don't remove more stock than there is.

34 An impossible sortie-rate request was detected (request exceeded maximum sortie rate).

Probable causes:

(1) No maximum sortie rate read in (implying a maximum of no sorties per day).

(2) For the given time of analysis, a base is required to have more sorties than allowed by the maximum sortie rate.

(3) Final time specified on maximum sortie rate is less than the maximum time of analysis requested, so that the effective maximum sortie rate for the concluding days of the scenario is zero.

Possible remedies:

(1) Include a maximum sortie rate which defines a maximum number of sorties per day for each day of analysis.

(2) Reduce the sortie rate at one or more bases.

(3) Increase the maximum sortie rate.

36 An impossible value was detected in the pipeline distribution.

Probable cause:

A negative variance-to-mean ratio read in for some LRU.

Possible remedy:

Change the variance-to-mean ratio to a nonnegative value.

37 An impossible value was detected in the backorder distribution.

Probable causes:

(1) A negative level of stock was input for some LRU.

(2) When using the facility to delete stock from the initial input levels at some later time, more stock was deleted than was originally read in.

Possible remedies:
(1) Read in nonnegative stock levels.
(2) Don't remove more stock than there is.

38 An impossible value was detected in the pipeline distribution.
Probable cause:
A negative variance-to-mean ratio read in for some LRU.
Possible remedy:
Change the variance-to-mean ratio to a nonnegative value.

40 Erroneous file read from File 3 (base-level pipeline).
Probable cause:
Error while reading unformatted internal file, probably due to some type of hardware failure.
Possible remedy:
Retry. Verify File 3 description statement in JCL.

41 An impossible value was detected in the stockage computation at base level.
Probable cause:
A negative variance-to-mean ratio read in for some LRU.
Possible remedy:
Change the variance-to-mean ratio to a nonnegative value.

42 LRU stock (including assets installed on aircraft) exceeds maximum allowed.
Probable causes:
(1) For some LRU at some time of analysis, the quantity per aircraft times the number of aircraft at a base plus the amount of input stock of that LRU at that base is greater than or equal to DMPMFMAX.
(2) During a stockage computation, enough stock was added by the stock-purchasing algorithm to create the problem described above.
Possible remedies:
(1) Input less stock.
(2) Increase DMPMFMAX and recompile.
(3) Use fewer aircraft.
(4) In the stockage computation, request either a lower goal, or a lower confidence level, or both.

43 Impossible value detected in pipeline distribution during LRU stockage computation.

Probable cause:

A negative variance-to-mean ratio read in for some LRU.

Possible remedy:

Change the variance-to-mean ratio to a nonnegative value.

44 LRU stock (including assets installed on aircraft) exceeds maximum allowed.

Probable causes:

(1) For some LRU at some time of analysis, the quantity per aircraft times the number of aircraft at a base plus the amount of input stock of that LRU at that base is greater than or equal to DMPMFMAX.

(2) During a stockage computation, enough stock was added by the stock-purchasing algorithm to create the problem described above.

Possible remedies:

(1) Input less stock.

(2) Increase DMPMFMAX and recompile.

(3) Use fewer aircraft.

(4) In the stockage computation, request either a lower goal or a lower confidence level.

45 Impossible value detected in pipeline distribution during stockage marginal analysis.

Probable cause:

A negative variance-to-mean ratio read in for some LRU.

Possible remedy:

Change the variance-to-mean ratio to a nonnegative value.

51 SRU stock (including assets installed on spare and installed LRSs) exceeds maximum allowed.

Probable causes:

(1) For some SRU at some time of analysis, the quantity per aircraft times the number of aircraft at a base plus the amount of input stock of that SRU at that base is greater than or equal to DMPMFMAX.

(2) During a stockage computation, enough stock was added by the stock-purchasing algorithm to create the problem described above.

Possible remedies:
(1) Input less stock.
(2) Increase DMPMFMAX and recompile.
(3) Use fewer aircraft.
(4) In the stockage computation, request either a lower goal or a lower confidence level.

53 SRU stock (including assets installed on spare and installed LRUs) exceeds maximum allowed.
Probable causes:
(1) For some SRU at some time of analysis, the quantity per aircraft times the number of aircraft at a base plus the amount of input stock of that SRU at that base is greater than or equal to DMPMFMAX.
(2) During a stockage computation, enough stock was added by the stock-purchasing algorithm to create the problem described above.
Possible remedies:
(1) Input less stock.
(2) Increase DMPMFMAX and recompile.
(3) Use fewer aircraft.
(4) In the stockage pass, request either a lower goal or a lower confidence level.

70 Impossible value detected in pipeline distribution during CIRF LRU stockage computations.
Probable cause:
A negative variance-to-mean ratio read in for some LRU.
Possible remedy:
Change the variance-to-mean ratio to a nonnegative value.

80 Peacetime demands for testing at a base exceed peacetime testing capability.
Probable causes:
(1) Total LRU failure rates exceed test-equipment capacity.
(2) Availability values were not set and therefore defaulted to zero (implying no testing capability).
(3) Insufficient test stands are available.
(4) Test times are too high.
Possible remedies:
(1) Decrease demands by lowering failure rates, reducing flying hours or removing aircraft from base.
(2) Set larger, or nonzero test-stand availability values.
(3) Add more test stands.
(4) Reduce test times.

90 Peacetime demands for testing at a CIRF exceed peacetime testing capability.

Probable causes:

(1) Total LRU failure rates exceed test-stand capacity.

(2) Alpha values were not set and therefore defaulted to zero (implying no testing capability).

(3) Insufficient test stands.

(4) Test times input too high.

Possible remedies:

(1) Decrease demands by lowering failure rates, reducing peacetime flying hours, removing aircraft, or serving fewer bases.

(2) Set larger, or nonzero alpha values.

(3) Add more test stands.

(4) Reduce test times.

GLOSSARY

Aircraft component support: the system of interrelated equipment, resources, personnel, facilities, and procedures that store, repair, and transport reparable and serviceable aircraft components.

Analysis time: a user-specified time at which Dyna-METRIC is to compute expected component pipelines and forecast aircraft performance statistics; expressed as days after the beginning of the wartime scenario.

Application fraction: the fraction of a base's aircraft that contain a particular component; normally 1.00 or 0.00, but may be some other value between those two extremes.

Attrition rate: the rate at which aircraft suffer air-to-air attrition in wartime; expressed as the fraction of sorties that fail to return to base; may vary over the wartime scenario.

Availability, test stand: the fraction of time that an average test stand is available to test components; excludes time the test stand is undergoing tests and repairs for internal malfunctions.

Backorder rate: the average rate at which backorders occur for components to repair a test stand; excludes test-stand component failures where base-level repair and supplies are sufficient to avoid degrading test-stand capability while the replacement component is on order; expressed as backorders (or fractions) per day.

Beddown: the number of aircraft deployed over time to specific operating locations; also, for test stands, the number of test stands deployed over time to specific bases.

Cannibalization: the practice of removing a serviceable component from one aircraft to repair another; also, the practice of removing subcomponents from one component to repair another; usually limited to situations where serviceable components are not immediately available and where replacing the component on the second aircraft will return that aircraft full operational status.

Component: a physically intact, identifiable unit that can be separated from an aircraft with minimum effort and special equipment at the flight line; distinguished from a subcomponent; a line replaceable unit (LRU).

Component testability: the probability that a test stand operating in a degraded, partially mission capable (PMC) mode due to at least one test-stand component backorder will be able to repair a given aircraft component.

Delay time: the duration of any procedure that must be performed to return a reparable component to serviceable on-hand status at a base's supply point; applies to administrative delays to remove, handle, and requisition a component from local or higher-echelon supply points, repair times, reparable (retrograde) transportation, and order and ship times.

Demand: a request for a replacement serviceable part; usually measured initially at base supply, but also used to indicate requisitions received at a CIRF or depot from facilities served by those supply echelons.

Deployment period: generally, the time span just before or after the beginning of a war when a force (including the associated logistics support systems) geographically redistributes its resources and lines of communication.

Depot: a combined repair/resupply facility typically located in the continental United States, which provides centralized storage, repair, and management of component assets and support processes.

Echo: term applied to various Dyna-METRIC reports that display the user's data and requests as read by the model; can be suppressed once the user is confident that the data are correct.

Failure rate: rate at which an aircraft component becomes inoperative as a result of flying the aircraft; expressed in failures per flying hour; distinguished from removal rate.

Flight line: an area at each base where aircraft are prepared for flying and recovered after flying; includes munitions loading, refueling, and component removal and replacement for line replaceable units (LRUs).

Flying intensity: the rate at which remaining available (unattrited) aircraft are tasked to fly; expressed as the number of sorties per remaining aircraft per day.

Forward transportation: the process (with associated delay times) of moving serviceable spare components from a centralized intermediate repair facility (CIRF) or a depot to a base.

Full cannibalization: a cannibalization policy which assures that the maximum number of fully mission capable (FMC) aircraft by removing serviceable components from aircraft already not fully mission capable (NFMC).

Hole, aircraft: the absence of a serviceable component to replace a reparable component removed from an aircraft; thus, a "hole" in the aircraft until a serviceable component fills it.

Indentured subcomponent: a component used solely to repair another component in a shop, such as a circuit card in an avionics system or a brake on a wheel; a subcomponent or shop replaceable unit (SRU).

Part: a generic term applied to both components and subcomponents.

Pipeline: conceptually, a representation of the component support system, a network of repair and transportation processes through which reparable and serviceable aircraft parts flow as they are removed from aircraft (or components), repaired, and requisitioned from other points of supply.

Pipeline quantity, total: the expected number of components originally removed from aircraft at a base that have not yet been returned to serviceable status in local supply; includes components in local repair and on requisition from other points of supply.

Pipeline segment: a single process in the component support system that is characterized by part arrivals over time, a delay time, and part departures over time.

Pipeline size: the expected number of components (or subcomponents) in a pipeline segment (or the entire pipeline).

Removal rate: the rate at which suspected failed components are removed from aircraft; includes demand rate but excludes undetected failures; includes erroneous removals that subsequently retest OK (RTOK).

Repair cycle time: a measured average delay time from the requisition of a serviceable component at base supply until the repaired component is returned to supply; includes average testing and repair times when the component is in work and queueing times when the component is awaiting maintenance (AWM); excludes administrative times, on-aircraft diagnosis times, and time spent awaiting parts (AWP).

Resupply cutoff: a temporary unavailability of resupply due to transportation or depot repair limitations; modeled in Dyna-METRIC as an initial period of user-specified duration where assets requisitioned from the CONUS are frozen in their peacetime locations immediately at the beginning of the scenario, and a subsequent period later in the scenario when resupply may again be cut off during a user-specified "start-to-finish" period.

Resupply time: a measured average delay time from the placing of a requisition until the arrival of the requisitioned component; always includes order and ship time; may include portions of repair time and retrograde transportation time if the point of supply has insufficient component assets on hand when the requisition is received.

Retrograde transportation: the process (with associated delay times) of moving reparable components from a base to a centralized intermediate repair facility (CIRF) or a depot.

Scenario: a sequence of planned processes and events that will be executed in a given potential wartime situation; includes the deployment of operating forces and support resources, and the employment of those forces and resources to meet wartime objectives.

Setup period: equipment and facility preparation time required after deploying a support unit to unpack, house, connect, calibrate, and certify repair equipment before component repair can begin.

Sortie: one wartime aircraft flying mission, from takeoff to touchdown.

Sortie rate: the average number of aircraft missions flown each day at each base divided by the number of aircraft at the base.

Subcomponent: a physically intact, identifiable unit that can be removed from a component in a base shop; a Shop Replaceable Unit (SRU).

Test stand: an integral test-equipment unit capable of diagnosing and supporting the repair of one component at a time.

Test station: a composite group of test equipment and personnel that typically diagnoses and repairs one component at a time; may represent aggregates of equipment like oscilloscopes and signal generators that test several different "black boxes" individually, or test teams that cooperatively repair a large component such as an engine.

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SUPPLEMENTARY

INFORMATION

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